DOCUMENT RESUME

ED 424 086 SE 060 852

AUTHOR	Famellette, Judy
TITLE	Science Standards: Making Them Work for You. Grades 3 and 4. Facilitor's Guide.
INSTITUTION	Association for Supervision and Curriculum Development, Alexandria, VA.
REPORT NO	ASCD-495243-LG
PUB DATE	1996-00-00
NOTE	77p.; For versions for primary grades and grades 5-6, see SE 060 851 and SE 060 853, respectively.
AVAILABLE FROM	Association for Supervision and Curriculum Development, 1250 N. Pitt Street, Alexandria, VA 22314; Video (stock #495243); Facilitator's Guide (stock #49243LG).
PUB TYPE	Guides - Non-Classroom (055) -- Non-Print Media (100)
EDRS PRICE	EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Academic Standards; *Classroom Techniques; Cognitive Style; *Curriculum Development; Elementary Education; Futures (of Society); Grade 3; Grade 4; Informal Assessment; Learning Activities; Mathematics Skills; Observation; *Science Education; Science Experiments; Science Process Skills; Teaching Methods; Videotape Cassettes; *Workshops
IDENTIFIERS	*National Science Education Standards

ABSTRACT

This facilitator's guide, and the videotape it accompanies, is designed to demonstrate ways in which the new visions of science education for the 21st century might be translated into classroom practice. The National Research Council's (NRC) National Science Education Standards, American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy, and other frameworks were used as guides in developing this series. The videotape presents views of real classrooms where science is being taught. Classroom situations are spontaneous and unscripted. The videotape shows how standards actually look in practice in the classroom and how teachers are guiding experiences that enable students to construct understanding and learn science processes. The guide contains information on conducting hands-on workshops including materials lists, materials sources, and handouts. The second video focuses on grades 3 and 4. In one lesson, third grade students observe the behavior of hermit crabs by performing simple experiments planned by the teacher and themselves. In another unit, children test different brands of paper towels to see which one will absorb the most water in 30 seconds. Finally, two hands-on lessons on simple machines engage students in devising their own mechanisms and taking apart familiar household appliances. (PVD)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

R. Brandt

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

2B

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

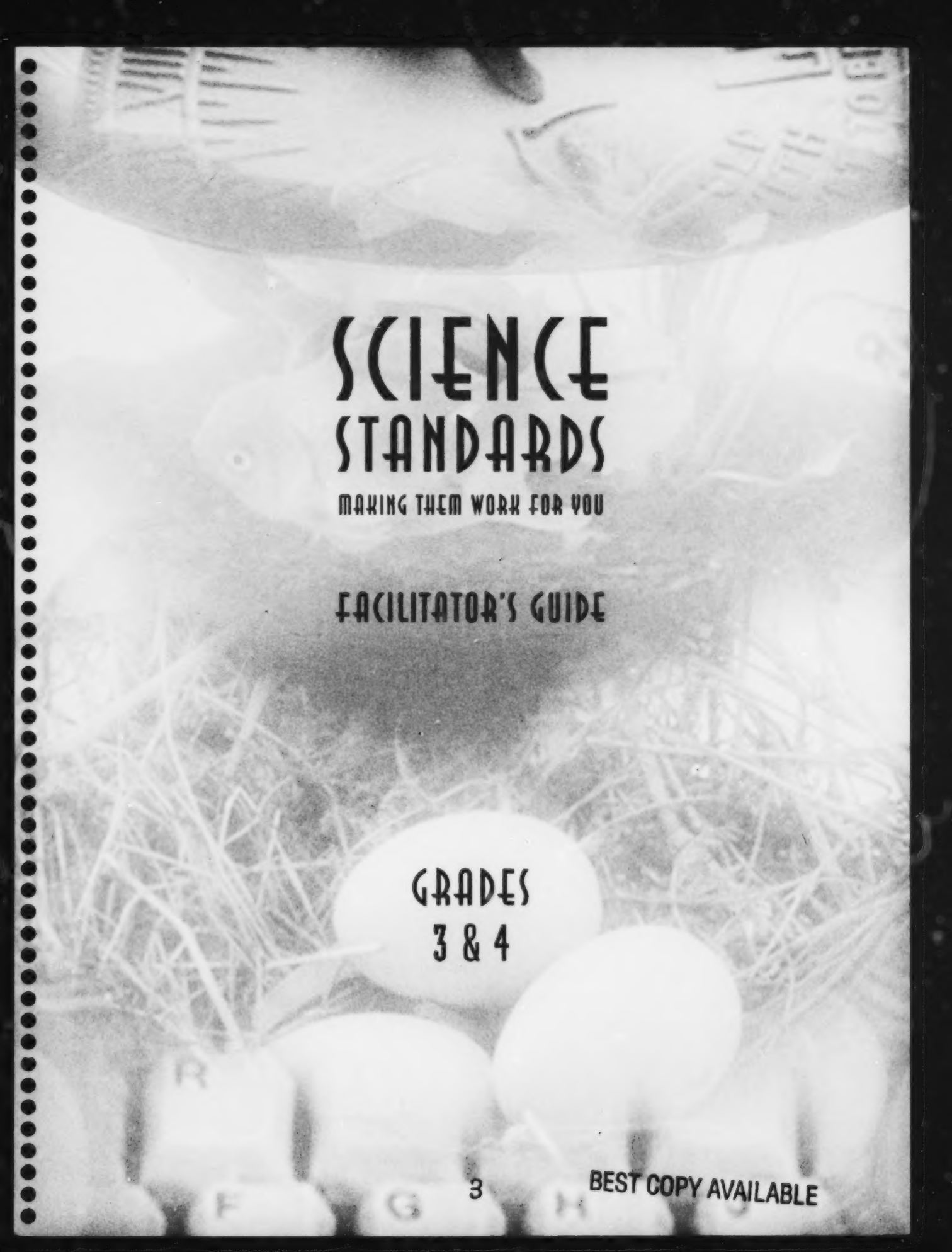
ED 424 086

SCIENCE STANDARDS

MAKING THEM WORK FOR YOU

GRADES 3 & 4

BEST COPY AVAILABLE



SCIENCE STANDARDS

MAKING THEM WORK FOR YOU

FACILITATOR'S GUIDE

GRADES 3 & 4

BEST COPY AVAILABLE

About the Developers

This guide was prepared by Judy Famellette, Elementary Science Teacher, Scarsdale School District, Scarsdale, New York; Loraine Corfield Voros, co-producer/director of the videos; and John Checkley, Senior Producer, ASCD.

The video program was produced by ASCD and the Teachers' Video Workshop. We gratefully acknowledge the support and participation of the Ramapo and Valhalla School Districts, New York; the Claremont Community School, Bronx, New York, the Rockland Teachers' Center, New York; and the Rockland County Board of Cooperative Educational Services.

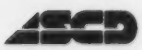
ASCD Staff

Video Production
Marcia D'Arcangelo, *Manager and Executive Producer*
John Checkley, *Senior Producer*
Beth Kabele, *Project Assistant*

Manual Production
Nancy Carter Modrak, *Manager, Editorial Services*
Carolyn R. Pool, *Associate Editor*
Gary Bloom, *Manager, Design and Production Services*
Karen Monaco, *Senior Designer*
Tracey A. Smith, *Production Coordinator*
Valerie Sprague, *Desktop Specialist*

ASCD, a diverse, international community of educators, forging covenants in teaching and learning for the success of all learners. Founded in 1943, ASCD is a nonpartisan, nonprofit, international education association with headquarters in Alexandria, Virginia.

Copyright © 1996 by the Association for Supervision and Curriculum Development, 1250 N. Pitt Street, Alexandria, VA 22314, and the Teachers' Video Workshop, Inc., 172 Viola Road, Monsey, NY 10952. All rights reserved. Handout materials may be reproduced for nonprofit, educational use only.



Association for Supervision and Curriculum Development
Telephone: (703) 549-9110 or 1-800-933-2723
Fax: (703) 299-8631
Internet access: gopher.ascd.org, http://www.ascd.org, or e-mail to info@ascd.org

ASCD Stock No.: 495243 LG
Videotape Stock No.: 495243

Science Standards: Making Them Work for You

Grades 3 & 4

Facilitator's Guide

Introduction

21st Century Science 3
Assumptions 3
Purpose of the Program 5
About the Program 5
Program Objectives 6
Role of the Facilitator 6

Workshops

Workshop 1 (about 1 hour) 11
Workshop 2 (half day) 14
Workshop 3 (full day) 20

Handouts

1. Self-Assessment 33
2. Reactions to Video 35
3. Small-Group Discussion/Planning 37

Lessons

Land Hermit Crabs 41
Paper Towel Testing 48
Constructivism 50
Mechanisms 51

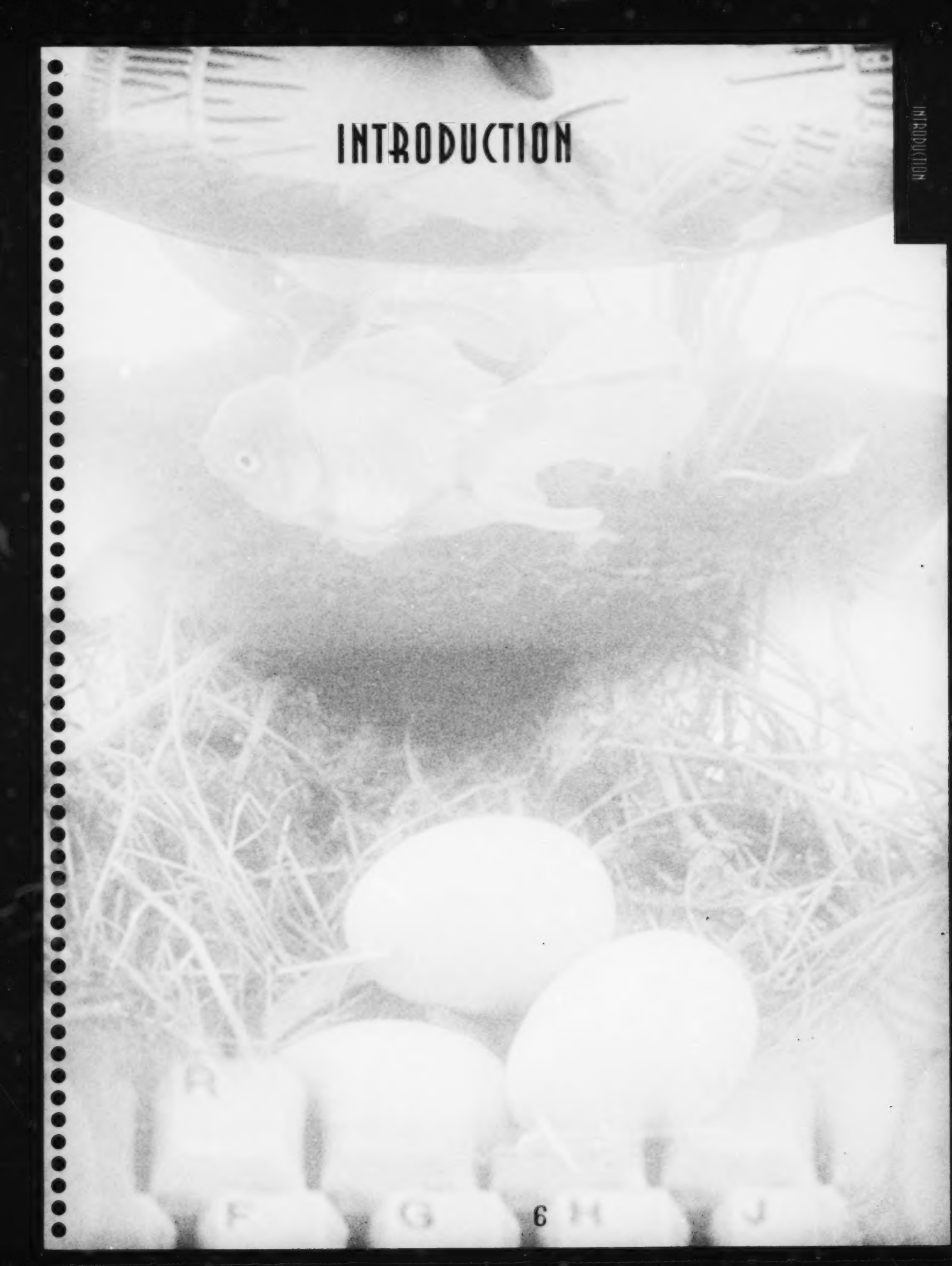
Overheads

1. Objectives of the Workshop 59
2. Our Classroom Covenant 61
3. A Look at School Environments—Contrasting Traditional and Constructivist Classrooms 63

References and Resources

References for Science Instruction 67
References for Lessons 67
Readings:
1. "Reinventing Science Education," by Scott Willis 69
2. "Student-Centered Inquiry," by Ramon E. Lopez and Jan Tuomi . . . 77
3. "PCs May Be Teaching Kids the Wrong Lessons," by Laurie Hays . . 79
4. "Some Software Nurtures Creativity," by Laurie Hays 81

INTRODUCTION



21st Century Science

By the time today's elementary school students graduate from high school, the world will be a very different place. Recent advances in science and technology have already caused dramatic changes in our way of life, and it's only the beginning. To prepare students for the challenges of the 21st century, scientists, educators, and other community members are formulating a new vision of science education, starting in the earliest grades. They are meeting to discuss what it means to be scientifically literate and what steps we need to take to help students achieve that literacy.

This new vision is reflected in several recent documents. *Benchmarks for Science Literacy* (American Association for the Advancement of Science, AAAS, 1993) details how students should progress toward the goal of science literacy described in *Science for All Americans* (Rutherford and Ahlgren 1990). *Benchmarks* lists the concepts that children should know by grades 2, 5, 8, and 12, in areas such as the "Living Environment," the "Physical Setting," and the "Nature of Technology." In *National Science Education Standards*, the National Research Council (NRC 1994—draft version) supports the goal of science literacy by giving standards not only for content and skills, but also for teaching science, teachers' professional development, assessment, and the entire science program and the system that provides it. The basic ideas of the AAAS *Benchmarks* and the NRC *Standards* are also found in *Frameworks for Curriculum and Instruction*, published by the National Center for Improving Science Education (1989), and in frameworks written by some states, such as California and New York.

These documents have a common goal: to produce a vision of science education that will guide reform and that will have an impact on curriculums and classrooms in the United States—and, indeed, in many other countries. It is the goal of this videotape series to show how that vision may be translated into classroom practice.

Assumptions

1. All children can learn science.

In fact, all children *must* learn science to live in an age of technology, where unprecedented amounts of information are available through computer networks. Science is not just for children of a particular gender, ethnicity, or socioeconomic class, nor is it just for future doctors, engineers and scientists, but for all students who will be facing the challenges of life in the 21st century.

2. ***Through their experiences, children (and adults) construct their own understanding of science and the world around them.***

As we grow, we constantly synthesize new information and experiences into what we already know. In this way, we make sense of our world. The study of science offers a wealth of opportunities for children to experience "discrepant events," which challenge them to search for new explanations and understandings.

3. ***Science content should be appropriate for the grade level taught.***

Activities and discussion should be designed to help children construct their own understanding of scientific concepts. Concepts should spiral through the curriculum, concentrating on thorough treatment of overarching ideas, rather than trying to "cover" a great deal of subject matter. ("Less is more.")

4. ***Children need experiences in the processes of science.***

Schools should use inquiry-oriented, hands-on, problem-solving techniques; and these strategies must replace traditional textbooks and worksheets. Like content, skills must also be appropriate for the child's developmental level, starting with basic skills such as observation, and progressing to the design of scientific experiments.

5. ***Science education should foster a positive attitude toward science.***

Teachers should be aware of the role of science studies in nurturing attitudes such as concern for the environment, understanding of what a scientist does, the value of scientific thinking, and an openness toward further learning.

6. ***Science education should start in the earliest grades.***

Children come to school with a natural curiosity about the world around them. Their curiosity and interest in science often disappears before they reach high school age. Teachers can capitalize on children's enthusiasm and use it to motivate learning, not just in science, but in other areas of the curriculum as well.

7. ***Children should learn the practical applications of science principles in the world.***

Technology, the science that deals with practical applications, is gaining momentum in the schools. Design projects and inventions help students to see the value of science in solving problems. Students also need to be aware of the adverse effects of technology and the difficult choices that must be made on a national level to use technology responsibly.

Purpose of the Program

This video series, *Science Standards: Making Them Work for You*, and the *Facilitator's Guides* are designed for administrators, teachers, parents, school board members, corporate and community leaders, and all others who are interested in improving science education at the elementary school level. We have used the NRC *Standards*, AAAS *Benchmarks*, and various frameworks as guides. The videotapes present views of science classrooms, highlighting practices that illustrate recently written science standards. The *Facilitator's Guides* contain information on conducting hands-on workshops, including lists of materials, sources of materials, and handouts.

About the Program

Teaching science presents unique problems for the elementary school teacher, problems related to classroom management, questioning techniques, and assessment of hands-on learning, to name just a few. Unfortunately, constraints of time, money, and scheduling usually prevent the one thing that would help teachers the most—observing fellow teachers at work. The videos in this series show nine classrooms where science is being taught. The classroom situations are spontaneous and unscripted. These are real classrooms representing a cross-section of the New York metropolitan area, from inner city to suburbia. We hope that these videos will enable teachers to see how standards actually look in classroom practice, and how teachers are guiding experiences that enable children to construct understanding and learn the processes of science.

This video-based staff development program consists of three 30-minute videotapes and *Facilitator's Guides*. Each videotape shows the lessons of three teachers, highlighting by "video footnotes" the practices that illustrate science standards. Tape 1 focuses on the primary grades (K–2), Tape 2 on grades 3–4, and Tape 3 on grades 5–6. All teachers should have an awareness of the concepts and skills leading up to the grades they teach, as well as the concepts and skills for which their teaching forms a foundation. Therefore, we recommend that participants view and discuss all the tapes to get an idea of the developmental flow of scientific concepts and skills, as well as an overview of issues such as curricular integration, authentic assessment, cooperative learning, and constructivism.

Program Objectives

At the end of this program, participants will be able to:

- Explain the significance of documents such as the NRC *Standards*, AAAS *Benchmarks*, and various frameworks.
- Design at least one science lesson that demonstrates effective management of materials, questioning techniques, integration, and authentic assessment.
- Describe the role that elementary science plays in preparing students for life in a technological information age.
- Recognize the motivational value of hands-on science activities.
- Identify issues and concerns involved in implementing science standards.
- Develop a personal or group plan of action related to the science standards.

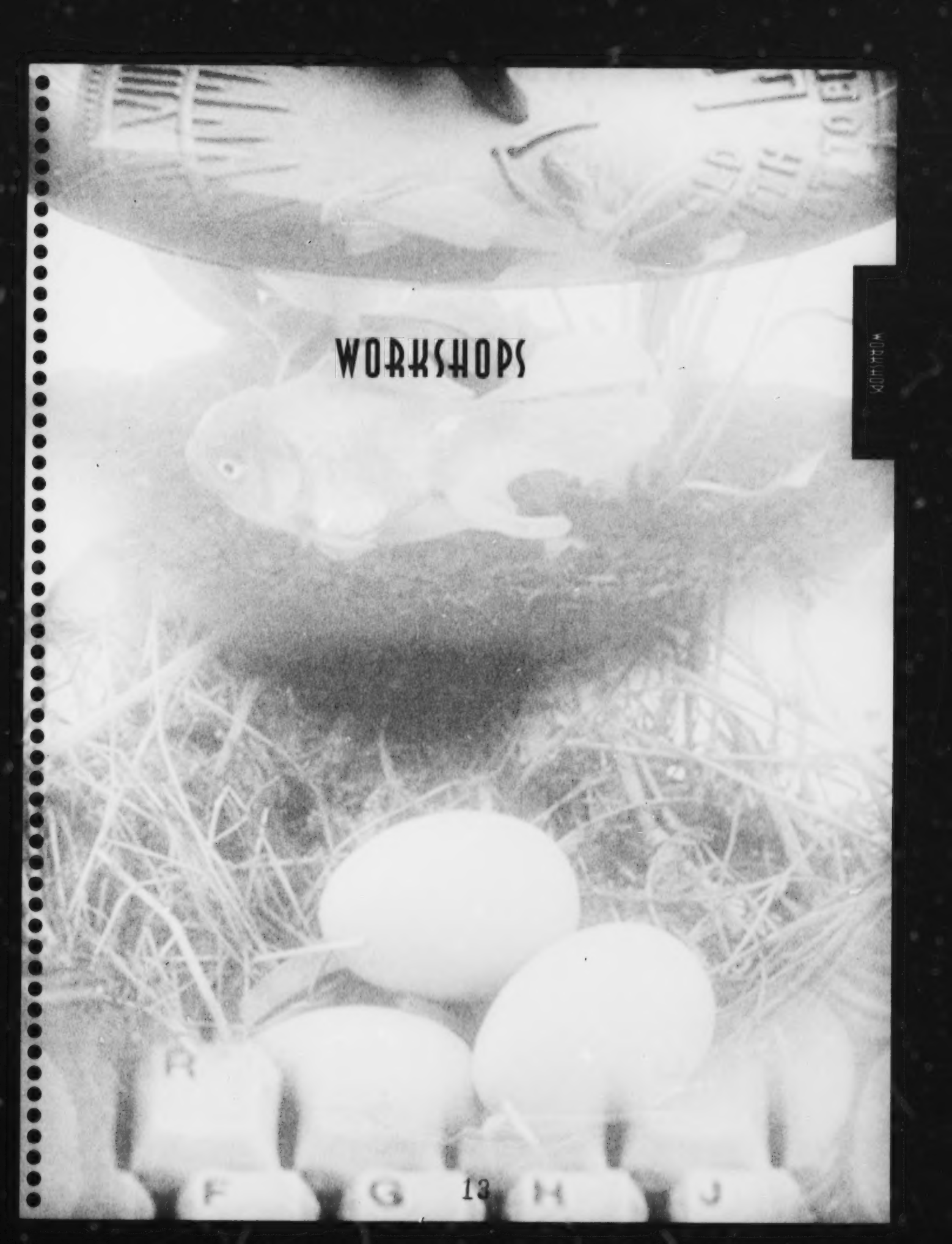
Role of the Facilitator

Whether you decide to simply show the videos to a group or conduct workshops, as facilitator of this viewing process, you could be a staff developer, principal, central office administrator, or teacher. As the facilitator, your preparation for the workshop and openness to discussion will enable you to help your group benefit from this program. Remember, you may be showing this video to a diverse group, and your background knowledge and outside reading will be beneficial. As a facilitator, your major responsibilities are as follows:

- **Read and View the Materials**
  - — Have you viewed the videotape?
  - — Have you read the *Facilitator's Guide*?
- **Prepare the Program Activities**
  - — Are you prepared to guide a group through the activities and discussions necessary in the workshops?
  - — Do you have a sound background in the concepts and process presented in the videos, or do you need to do further reading?
  - — Have you tried the hands-on activities to ensure that the presentation goes smoothly?

- **Check the Room and the Seating**
  - — Have you reserved a room that is large enough, with ample seating and tables for hands-on activities? (Tables for groups of 4 work best, to model cooperative grouping.)
  - — Is the room conducive to a follow-up group discussion?
- **Arrange for a Working VCR and Monitor, and Ensure Proper Electrical Fittings**
  - — Have you arranged for the use of a VCR and monitor? (One 23–25-inch monitor will suffice for up to 25 participants.)
  - — Have you tested both machines to ensure that they are in working condition?
  - — Are the electrical outlets in the room in working order?
  - — Do you have power cords with adapters that will allow you to use the VCR?
- **Prepare Materials**
  - — Have you gathered the necessary materials for the hands-on workshops, and arranged them in trays or bags to facilitate distribution, and to model an appropriate classroom management procedure?
  - — Have you tried the activities, to see if they work for you?
  - — Have you duplicated enough handouts for all participants?
  - — Are there any supplementary articles you would like to give as handouts? (See "References and Resources" section.)
  - — Have you prepared transparencies from the "Overheads" section of this guide?
  - — Have you duplicated overheads, if necessary?
  - — Do you have extra, blank transparencies available?
- **Arrange for Other Equipment**
  - — Does the room have an overhead projector, a screen, and perhaps a flipchart?
  - — Do you have a sufficient supply of pens or markers for charts or transparencies?

- **Announce the Program**
  - — Have you specified clearly the day, month, time, and location for the program? (Remind participants to bring pencils and notepads.)
  - — Because of the subject matter of this program, have you specifically invited parents, community leaders, and business representatives?
- **Make Other Arrangements**
  - — Have you prepared the agenda, with times for breaks?
  - — Have you arranged for refreshments?


WORKSHOPS
WORKSHOP
F
G
H
J

Workshop 1

We suggest three viewing formats to meet the needs of diverse audiences. This workshop offers an introduction to the NRC *Science Standards*, AAAS *Benchmarks for Science Literacy*, and various science frameworks, for a group of participants who would like an overview of the topic, and a look at how these documents apply to classroom practice. This format would be ideal for an evening community-school meeting, a school board presentation, or a parent-teacher forum. It will be effective for an audience that includes parents, teachers, administrators, and community representatives.

We suggest the following agenda for this 70-minute session:

Agenda and Time Guide: Workshop 1

Activities	Time (minutes)
Welcome and Introductions	5
Video Viewing	30
Making Science Standards Work for You (Grades 3 & 4)	
Reflections	20
Approximate Workshop Time	70 minutes

Facilitator's Note

Whenever appropriate, refer to the quotes from the NRC Standards, AAAS Benchmarks, and various science frameworks, printed in the margin.

Workshop Materials

For this workshop, you will need copies of Handouts 1 and 2 for all participants, as well as a flipchart or chalkboard and appropriate markers. If this is a large group, an overhead projector with blank transparencies might be more effective as a way to make notes that everyone can see. If you think participants would be interested, you might distribute one or more of the readings from the "References and Resources" section.

Welcome and Introductions (5–10 minutes)

1. Welcome all participants. Introduce yourself and explain your role as workshop facilitator. As the facilitator, you will guide the group through the workshop activities to help them address the following questions (place relevant questions on flipchart/overhead transparency):

   - What are the implications of science standards in our school (or district)?

- How is our school (or district) responding to the need for better science education?
- What kind of commitment is involved in meeting the standards for science education, in terms of resources, support, and staff development?
- What part(s) of the video interested you most?
- What questions would you like to ask the teachers depicted in the video?
- Do you think this video should be shared with a wider audience in our school, district, and community? Why?
- What activities have you seen or done that illustrate the science standards?

2. Depending on the size of the group and whether the participants know each other, you may want to set aside time for participants to introduce themselves individually.
3. Distribute Handout 1, "Self-Assessment." After participants review the handout, ask them to state why they are interested in learning about science standards and to describe briefly the extent to which they are familiar with standards. Explain that they will not be turning the handout in; but they may wish to share their thoughts later in the workshop.

Video-Viewing Activity (35 minutes)

1. Call participants' attention to the list of questions from your flipchart or overhead transparency.
2. Ask participants to consider, while watching the program, the effect science standards have on all students and on the roles of staff members in the featured schools. Also ask them to consider what it would take to implement the standards in their curriculum.
3. View the video (30 minutes).

Reflections (20 minutes)

1. Distribute Handout 2, "Reactions to Video," and allow participants 10 minutes to record their reactions.

2. Invite participants to engage in a discussion, based on their reactions to the video. Record their reactions on a chalkboard or flipchart.

3. After the discussion, ask participants to share their answers to the original list of questions.

4. Close the workshop by reviewing some of the key points mentioned during the discussion, and address any questions the participants may have about additional workshops.

Workshop 2

We suggest holding this half-day workshop for those who are familiar with the content and process of elementary science education, but wish to explore and discuss issues such as integration, assessment, classroom management, and construction of scientific concepts. This program, *Science Standards: Making Them Work for You (Grades 3 & 4)*, is intended primarily for educators, parents, community members, businesspeople, and others interested in what recently written science standards have to say about science education for the primary grades. The times listed here include the time required for viewing the video and suggested times for completing the follow-up activities. You may wish to allow additional time for group discussion.

Facilitator's Note

Whenever appropriate, refer to the quotes from the NRC Standards, AAAS Benchmarks, and various science frameworks, printed in the margin.

Agenda and Time Guide: Workshop 2

Activity	Time (minutes)
Introductory (Warm-Up) Activity	30
View Video	30
Science Standards: Making Them Work For You (Grades 3 & 4)	
Break	15
Hands-On Activity—Paper Towel Testing	60
Follow-Up Activities	30
Concluding Activity	15
Approximate Total Workshop Time	3 hours

Workshop Materials

For this workshop, you will need, for each participant (listed in the order you will need them), copies of:

- Handout 1
- Handout 2
- The entire "Lessons" section of the guide. (Optional—Use this for audiences that need detailed instructions and background material.)
- Any readings in the "References and Resources" section that you feel are appropriate.

You will also need to make the following transparencies, from the "Overheads" section: (listed in the order you will need them)

- Overhead 1
- Overhead 3

You will also need the following materials, for each group: a plastic or Styrofoam tray, 3 or 4 different brands of paper towels, including at least one major, well-advertised brand, and at least one generic brand. Try to get distinctive patterns or textures, to avoid confusion. You will also need a variety of containers and measuring devices from which participants can choose, including measuring cups, spoons, rulers, containers, stirrers, medicine droppers, small bottles, and water and a place to dispose of waste water.

Introductory (Warm-up) Activity (30 minutes)

1. At the door, have a sign-in sheet for participants to record their names, addresses, and phone numbers.

2. Introduce yourself to the participants. In addition to telling your name and what you do, write your name on a flipchart or on the board. Explain your role as the workshop facilitator. As a facilitator, you will guide the group through the workshop; you will help them meet the workshop goals. Call their attention to the goals on the overhead, flipchart or board. Briefly discuss these objectives. (Show Overhead 1, "Objectives of the Workshop."

   Tell participants the following:

   - **In this activity, we will focus on what we want to accomplish in this workshop, what we think the NRC *Science Standards*, the AAAS *Benchmarks for Science Literacy*, and various science frameworks mean to classroom practice, and why we may want to change our approach to teaching science.**

4. Distribute Handout 1, "Self-Assessment." Explain the purpose of the activity as follows:

   - **All of us have a common goal—to improve education so our children are prepared to meet the demands of our technological society. What we may not agree on is how we proceed to achieve this goal. By completing this handout, we can start this workshop with a better understanding of our feeling**

about the role of science in elementary education, and the implications of science standards, benchmarks and frameworks.

Allow participants about 5 minutes to complete the form.

5. Ask participants to share their answers with others (groups of three or four).

6. Ask the groups to report their answers to questions 1 and 2. If time allows, record the answers on the flipchart or a transparency.

Viewing the Videotape (30 minutes)

1. Introduce the videotape by telling the participants:

   - **Recent concern about the status of science education has stimulated the creation of a number of documents that describe standards for science education. Documents like the NRC *Science Standards*, the AAAS *Benchmarks for Science Literacy*, and various science frameworks outline what students need to know and do to be scientifically literate. The video we're about to see:**

     - **introduces examples of some of the science standards,**
     - **presents examples of classrooms where standards are being implemented, and**
     - **shows what the standards actually look like in classroom practice.**

2. Before playing the video, say to participants:

   - **As you watch the program, consider what each teacher is doing and think about whether it should and could work in your school or class. What adaptations, if any, could you make for your class?**

3. Answer any simple and direct questions. Then view the entire videotape (30 minutes).

Break (15 minutes)

A break following the video will give the audience a chance to discuss informally what they have seen and heard so far. They can begin to internalize and organize their thoughts for the remainder of the workshop.

Hands-On Activity—Paper Towel Testing (60 minutes)

1. Introduce the activity by saying:

   - **In the video you've just seen, a teacher gives her 3rd grade students an open-ended problem: to test different brands of paper towels to see which one will absorb the most water in 30 seconds. She does not give them instructions for performing the test, but has available materials from which they can choose. By designing the experiment and making their own decisions about materials and procedures, students begin to construct understanding of a "fair test." In this activity, you'll get a chance to see how your group would solve the problem.**

   Model the Paper Towel Testing lesson (see the preceding list, "Workshop Materials").

2. The following problem is the focus of this lesson:

   Problem: Which kind of paper towel absorbs the most water in 30 seconds?

3. Discuss the advertising claims made by various products. How can we tell whether the claims are true?

4. Tell participants that they are going to devise tests to determine what kind of paper towel absorbs most quickly by seeing how much water each one can pick up in 15 seconds. (In the video, it was necessary for the teacher to set the ground rules, allowing 15 seconds for each test, counting one paper towel as a unit, regardless of its size, and requiring that experiments be conducted on a tray, for easy cleanup.)

5. Review the procedure for designing an experiment: stating the problem, making a prediction, deciding on the materials to be used, writing a list of materials, and deciding on the procedure to be followed.

6. While the groups are working to design the experiment, circulate around the room, listening to conversations and asking questions, but not giving directions on how to conduct the investigation. Take notes on any interesting conversations, to share with the group later.

7. After each group has decided on the procedure and materials, allow one person from the group to get the supplies, and let the group conduct the experiment they have designed.

If students themselves participate in scientific investigations that progressively approximate good science, then the picture they come away with will likely be reasonably accurate.
AAAS Benchmarks for Science Literacy

Students should become increasingly comfortable with developing designs and analyzing the product.
AAAS Benchmarks for Science Literacy

In everyday life, people are bombarded with claims, claims about products, about how nature or social systems or devices work, about their health and welfare, about what happened in the past and what will occur in the future. These claims are put forth by experts (including scientists), by honest people and charlatans. In responding to this barrage, trying to separate sense from nonsense, knowledge helps.
AAAS Benchmarks for Science Literacy

8. Circulate around the classroom to monitor progress, ask guiding questions, and listen to conversations about the project.

9. When participants are finished testing, have them clean the desk areas, and return the materials to the supply station.

10. Facilitate the discussion by asking participants:

    - **Did all the groups obtain the same results? (probably not) What procedures were followed? Did any problems arise? How were they resolved? What would you do differently if you were to do this test again?**

      What did you learn about the properties of paper towels, and their similarities and differences? What other characteristics would you like to test?

11. Share with the group any interesting conversations that you noticed, indicating different ways of solving the problem.

    Suggestions for further discussion:

    Which paper towel is most economical? Can you always judge economy by the number of sheets? Do bigger-sized sheets of paper towels always absorb more? Would the results be the same if a longer time were allowed for the experiment?

12. Ask the group to comment on the constructivist aspect of the lesson. What are the benefits? Drawbacks? Is the constructivist philosophy illustrated in any of the other segments of the video? If so, where?

13. Show Overhead 3, "A Look at School Environments—Contrasting Traditional and Constructivist Classrooms." Review and discuss the two views.

14. If time permits, discuss the pros and cons of having a science specialist in each school.

The idea of a fair test is possible for many students to begin to consider by fourth grade.
Draft, NRC Science Education Standards

By gaining lots of experience doing science, becoming more sophisticated in conducting investigations, and explaining their findings, students will accumulate a set of concrete experiences on which they can draw to reflect on the process.
AAAS Benchmarks for Science Literacy

From the earliest grades, students should experience science in a form that engages them in the active construction of ideas and explanations and enhances their opportunities to develop the skills of doing science.
Draft, NRC Science Education Standards

Follow-up Activities (30 minutes)

Here are some questions that you may be asking after viewing the video and participating in one of the activities. Discuss the following and note some of the participants' comments regarding:

- What is your general reaction to the activities and issues shown in the videotape?

- What special considerations need to be addressed by the teacher, in using the Standards, Benchmarks, and Frameworks as guides to science education?
- What kind of district and administrative support is necessary for a teacher to use the Standards, Benchmarks, and Frameworks as guides to science education?
- How do the activities shown in the video compare with those in your school?
- How do the assessment methods shown in the video compare with those in your school?
- What evidence did you see that science was integrated with other areas, such as math, literature, art, social studies?
- What kinds of classroom management techniques were shown?
- What concerns do you have about the implications of the NRC *Standards* and AAAS *Benchmarks* to elementary science education?

Concluding Activity (15 minutes)

1. Distribute Handout 2, "Reactions to Video," and explain the following to participants:

   - **In a few minutes, I'm going to ask for volunteers to begin forming an elementary science planning team to consider the issues raised in this workshop and suggest possible strategies with which to address them. To help you in this task, you will have the notes I've taken on the discussion and the summaries written by the recorder in each group. At a future meeting, the team will present suggestions on possible efforts to use science standards to institute change in our science program.**

2. After participants have had sufficient time to write their responses, collect the handout.
3. Ask volunteers to sign up on the sheet you will distribute, if they are interested in being a member of a planning/leadership team.
4. Set a meeting time in the next couple of weeks for the team to meet.

Workshop 3

This full-day workshop is suggested for beginning teachers and others who are unfamiliar with the content and process of elementary science education, and wish to explore and discuss issues such as integration, assessment, classroom management, and construction of scientific concepts, within the context of actual classroom situations. This program, *Science Standards: Making them Work for You (Grades 3 & 4)*, is intended primarily for educators, parents, community members, businesspeople, and others interested in how recently written science standards can affect science education. The times listed here include the time required for viewing the video and suggested times for completing the hands-on and follow-up activities. You may want to adapt this schedule by showing the video in three 10-minute segments, followed by the appropriate activities, or by conducting the activities first, then showing the video.

Facilitator's Note

Whenever appropriate, refer to the quotes from the NRC Standards, AAAS Benchmarks, and science frameworks, printed in the margin.

Agenda and Time Guide: Workshop 3

Activity	Time (minutes)
Introductory (Warm-Up) Activity	25
View Video	30
Science Standards: Making Them Work For You (Grades 3 & 4)	
Hands-on Workshop—Land Hermit Crabs	45
Break	15
Hands-on Workshop—Paper Towel Testing	45
Lunch Break	60
Hands-on Workshop—Mechanisms	45
Follow-Up Activities	30
Small-Group Planning by Grade Level	30
Sharing and Concluding Activity	30
Approximate Total Workshop Time	5 hours

Workshop Materials

For this workshop, you will need, for each participant (listed in the order you will need them), copies of:

- Handout 1
- The entire "Lessons" section of the guide.

- Handout 2
- Handout 3
- Any readings in the "References and Resources" section that you feel are appropriate.

You will also need to make the following transparencies, from the "Overheads" section (listed in the order you will need them):

- Overhead 1
- Overhead 2
- Overhead 3

You will also need the following materials:

For the Hermit Crab Activity

- Hermit crabs (at least one per table, but it is better to have two or three for each table, for comparison purposes, and to ensure that there is at least one that is not too shy to come out and perform)
- Hermit crab habitat, as described in the Lessons section, page 47
- Clear plastic containers (at least one per table)
- Water (not too cold or hot, about 70–85 degrees)

For the Paper Towel Activity

- For each group: a plastic or Styrofoam tray
- 3 or 4 different brands of paper towels, including at least one major, well-advertised brand, and one generic brand. Try to get distinctive patterns or textures, so that participants can easily distinguish one from the other.
- A variety of containers, measuring devices, etc. from which participants can choose, including measuring cups, spoons, rulers, containers, stirrers, medicine droppers, etc.
- Water, and a place to dispose of waste water

For the Mechanisms Activity

For the demonstration:

- Sample mechanisms for demonstration, with the levers hidden (see Lessons, illustration on page 54)

For each child or group:

- A large piece of corrugated cardboard, about 20" × 20"
- 5–10 one-inch-wide strips cut from corrugated cardboard, about 10–15" long
- Two-legged paper fasteners
- Ballpoint pen or other object for making holes in the cardboard
- Construction paper or drawing paper for the figures

Introductory (Warm-up) Activity (25 minutes)

1. Write the workshop objectives on the overhead, Flipchart, or board before the participants arrive.
2. At the door, have a sign-in sheet for participants to record their names, addresses, and phone numbers.
3. Introduce yourself to the participants. In addition to telling your name and what you do, write your name on a flipchart or on the board. Explain your role as the workshop facilitator. As a facilitator, you will guide the group through the workshop; you will help them meet the workshop goals. Call their attention to the goals on the overhead, flipchart or board (show Overhead 1, "Objectives of the Workshop"). Briefly discuss these objectives.
4. Tell participants the following:
   - **In this activity, we will focus on what we want to accomplish in this workshop, what we think the NRC *Science Standards*, the AAAS *Benchmarks of Science Literacy*, and various science frameworks mean to classroom practice, and why we may want to change our approach to teaching science.**
5. Distribute Handout 1, "Self-Assessment." Explain the purpose of the activity, as follows:
   - **All of us have a common goal—to improve education so our children are prepared to meet the demands of our technological society. What we may not agree on is how we proceed to achieve this goal. By completing this handout, we can start this workshop with a better understanding of our feeling about the role of science in elementary education, and the implications of the NRC *Science Standards*, the AAAS *Benchmarks*, and the science frameworks.**

Allow participants 5 minutes to complete the Self-Assessment form.

6. Ask each participant to share their answers with others (groups of three or four).

7. Ask the groups to report their answers to questions 1 and 2. If time allows, record the answers on the flipchart or a transparency.

Viewing the Videotape (30 minutes)

1. Introduce the videotape by telling the participants:

   - **Recent concern about the status of U.S. science education has stimulated the creation of a number of documents that describe standards for science education. Documents like the National Science Standards, and the Benchmarks for Science Literacy outline what students need to know and do in order to be scientifically literate. The video we're about to see:**

     - **introduces examples of some of the science standards,**
     - **presents examples of classrooms where standards are being implemented, and**
     - **shows what the standards actually look like in classroom practice.**

2. Before showing the video, say to participants:

   - **As you watch the program, consider what each teacher is doing and think about whether it should and could work in your school or class. Also, think about the adaptations, if any, could you make for your class?**

3. Answer any simple and direct questions. Then view the entire videotape. (30 minutes).

Hands-On Activity—Land Hermit Crabs (45 minutes)

1. Introduce the activity by giving the following instructions:

   - **In the first segment of the video we've just seen, 3rd graders observed the behavior of hermit crabs by performing safe and simple experiments planned by the teacher and by themselves. In doing so, they learned about a living creature and gained experience in scientific thinking at their own level.**

The AAAS *Benchmarks* and NRC *Standards* recommend that children have the opportunity for firsthand experience with a variety of living animals, to become familiar with their structure and the functions of their different parts. Children can observe and compare the animals, their needs, and the ways in which their habitats, behaviors, and structural adaptations enable them to meet their needs. Also, caring for classroom animals gives children a sense of responsibility and concern for living creatures.

Lead the participants in the model Land Hermit Crab lesson (see the preceding list, "Workshop Materials").

Students should have the opportunity to learn about an increasing variety of living organisms, both the familiar and the exotic.
AAAS Benchmarks for Science Literacy

During the elementary grades, children build understanding of biological concepts through direct experience with living things.
Draft, NRC Science Standards

The study of organisms should include observations and interactions within the natural world of the child.
Draft, NRC Science Standards

2. The following problem is the focus for this lesson. Call participants's attention to the problem and the safety notes.

   Problem: What is the hermit crab like?

   Safety notes: It is safe to hold the hermit crab by its snail shell, and usually safe to allow the crab to crawl in the palm of the hand. However, hermit crabs can give a painful (but not fatal) pinch, if they are afraid of falling. If this happens, holding the hermit crab under cold running water will usually make it let go without harm to the hermit crab. Hermit crabs may also be handled with large salad tongs, if teachers or students are squeamish about handling them.

   Although hermit crabs don't have any diseases in common with humans, it is good practice to wash your hands before and after handling any animal.

3. Discuss with the participants the animals they have seen that live by water. Talk about what they look like, what they do, and so forth.

4. Tell the participants that they will be observing an animal, perhaps one that they haven't seen before. Tell them that the animal is a hermit crab. You may want to use the K–W–L format, writing in columns on the board their answers to the questions, "What do you already **K**now about hermit crabs?" and "What do you **W**ant to find out?" Make a column labeled, "What we **L**earned," and maybe one labeled "What we still want to know." Some suggested questions are:

   - How does the hermit crab walk? See? Eat? Smell?
   - How many legs does it have?
   - What are its legs used for?

5. Before distributing the hermit crabs, talk about the importance of humane treatment. Also warn them about the hermit crab's pinchers. (See previous **safety note**.)

6. Distribute the hermit crabs, either by placing them in the plastic containers on the tables/desks, or by having one person from each table come to the supply area to get a container and hermit crab(s). Adding a little water, about a half inch (1 centimeter) to the container will help to coax the hermit crabs out of the shell to walk around.

7. When participants have observed the hermit crabs at their own tables, exchange the containers, so that they get a chance to observe the variety of hermit crabs and their snail shells.

8. When all the participants have had a chance to observe the hermit crabs, collect them and return them to their "habitat."

9. Discuss the observations, asking questions such as

   - "How does the hermit crab see?"
   - "Are its eyes like ours?"
   - "How are they alike or different?"
   - By asking questions that begin with "What do you think . . . ?" "How do you know . . . ?" and "How can we find out?" you will be modeling the kinds of questions that encourage children to think objectively. Were participants able to answer any questions from the "What we want to know" list? If so, write them in the column under "What we learned." As shown in the video, some questions need to be answered by looking in a book. Direct the participants' attention to the Lessons section, which contains background information on hermit crabs.

10. The packet also contains a copy of the "covenant" that the class in the video agreed on at the beginning of the year. An outstanding feature of this class was its family-like atmosphere, conducive to creativity and the sharing of ideas. Show Overhead 2, "Our Classroom Covenant," and encourage participants to read and discuss this sample covenant. Ask what kind of covenant they think their students would write.

Break (15 minutes)

A break at this time will give you the opportunity to check the materials for the next activity.

Hands-On Activity—Paper Towel Testing (45 minutes)

1. Introduce the activity by saying:

   - **In the video you've just seen, a teacher gives her 3rd grade students an open-ended problem: to test different brands of paper towels to see which one will absorb the most water in 30 seconds. She does not give them instructions for performing the test, but has available materials from which they can choose. By designing the experiment, and making their own decisions about materials and procedures, students begin to construct understanding of a "fair test." In this activity, you'll get a chance to see how your group would solve the problem.**

   Lead the participants in the model Paper Towel Test lesson (see the preceding list, "Workshop Materials").

2. The following problem is the focus of this lesson:

   Problem: Which kind of paper towel absorbs the most water in 30 seconds?

3. Discuss the advertising claims made by various products. How can we tell whether the claims are true?

4. Tell participants that they are going to devise tests to determine what kind of paper towel absorbs most quickly by seeing how much water each one can pick up in 30 seconds. (In the video, it was necessary for the teacher to set the ground rules, allowing 30 seconds for each test, counting one paper towel as a unit, regardless of its size, and requiring that experiments be conducted on a tray, for easy cleanup.)

5. Review the procedure for designing an experiment: stating the problem, making a prediction, deciding on the materials to be used, making a list, and describing the procedure to be followed.

6. While the groups are working to design the experiment, circulate around the classroom, listening to conversations and asking questions, but not giving directions on how to conduct the

If students themselves participate in scientific investigations that progressively approximate good science, then the picture they come away with will likely be reasonably accurate.
AAAS Benchmarks for Science Literacy

Students should become increasingly comfortable with developing designs and analyzing the product.
AAAS Benchmarks for Science Literacy

In everyday life, people are bombarded with claims, claims about products, about how nature or social systems or devices work, about their health and welfare, about what happened in the past and what will occur in the future. These claims are put forth by experts (including scientists), by honest people and charlatans. In responding to this barrage, trying to separate sense from nonsense, knowledge helps.
AAAS Benchmarks for Science Literacy

investigation. Take notes on any interesting conversations, to share with the group later.

7. After each group has decided on the procedure and materials, allow one person from the group to get the supplies, and let the group conduct the experiment they have designed.

8. Circulate around the classroom to monitor progress, ask guiding questions, and listen to conversations about the project.

9. When participants are finished testing, have them clean the desk areas and return the materials to the supply station.

10. Discuss the results with the class, using the following questions as guides:

    - **Did all the groups obtain the same results? (probably not) What procedures were followed? Did any problems arise? How were they resolved? What would you do differently if you were to do this test again?**

      What did you learn about the properties of paper towels, and their similarities and differences? What other characteristics would you like to test?

The idea of a fair test is possible for many students to begin to consider by fourth grade.
Draft, NRC Science Standards

11. Share with the group any interesting conversations that you noticed, emphasizing different ways of solving the problem, comments that could be used to assess understanding, and so forth.

    Suggestions for further study:

    Which paper towel is most economical? Can you always judge economy by the number of sheets? Do bigger-sized sheets of paper towels always absorb more? Would the results be the same if a longer time were allowed for the experiment?

12. Ask the group to comment on the constructivist aspect of the lesson. What are the benefits? Drawbacks? Is the constructivist philosophy illustrated in any of the other segments of the video? If so, where?

13. Show Overhead 3, "A Look at School Environments—Contrasting Traditional and Constructivist Classrooms." Review and discuss the two views.

From the earliest grades, students should experience science in a form that engages them in the active construction of ideas and explanations and enhances their opportunities to develop the skills of doing science.
Draft, NRC Science Standards

By gaining lots of experience doing science, becoming more sophisticated in conducting investigations, and explaining their findings, students will accumulate a set of concrete experiences on which they can draw to reflect on the process.
AAAS Benchmarks for Science Literacy

Lunch Break (60 minutes)

Hands-On Workshop—Mechanisms (45 minutes)

1. Introduce the activity by giving the following instructions:

   - **The final segment of the video shows two hands-on lessons that are part of a unit on simple machines. In the first one, students are challenged to figure out the hidden lever mechanism that controls the motion of cardboard figures, and to devise their own mechanisms. In this activity, you'll get a chance to try your hand at producing your own lever mechanism.**

   Lead participants in the model Hidden Mechanism lesson (see the preceding list, "Workshop Materials").

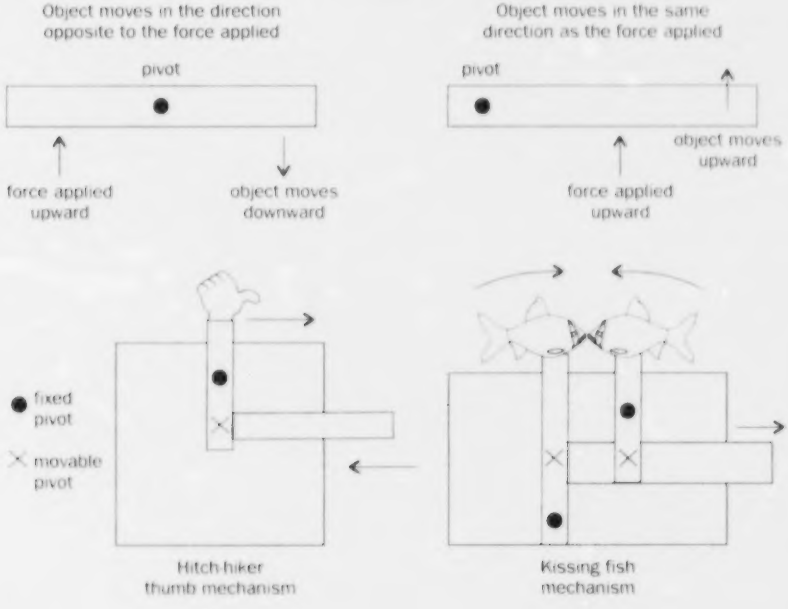
Children should design and make things with simple tools and a variety of materials.
AAAS Benchmarks for Science Literacy

2. The following problem is the focus of this lesson:

   Problem: How can we make a lever mechanism that will move figures in different directions?

3. Using the sample mechanisms with hidden levers, show the participants how these mechanisms move. Ask them to describe what they think is inside, and how the mechanisms work.

Linkages



4. Tell them that they will design mechanisms of their own, using the cardboard and fasteners. Show them how to use the ballpoint pens to make holes in the cardboard, and fasten them together with two-legged fasteners to make the pivots.

5. Ask the participants to work in groups of two to four to plan and build their mechanisms, sending a person to the supply table to pick up materials as needed.

6. Circulate through the room to ask guiding questions, give suggestions, and assess understanding. Make a note of any interesting conversations.

7. When participants have finished their projects, ask them to share them with the rest of the group, and let group members guess how they work. After discussions, the mechanisms may be turned around to show the levers that work them.

8. Ask participants to reflect on their experience. What did they learn? Did anything surprise them? How were they able to work as a group, dividing up the work, and designing the project?

9. Ask for reactions to the lesson in the video where students took apart appliances. Remind them of the importance of observing the safety rules:

   - Wear safety goggles at all times when taking apart appliances.
   - Cut the wires and plugs off all appliances before taking them apart. (Appliances should not be plugged in after being dismantled.)
   - Hammers should only be used with the teacher's permission and supervision.
   - Take apart the appliances carefully, piece by piece, without breaking anything. Try to remember where all the parts came from.
   - Try to put the appliance back together when you are finished.
   - Don't try to take apart television sets. They may contain dangerous residual electricity, even when unplugged.

Classrooms can have "take-apart" stations where a variety of familiar hardware devices can be taken apart (and perhaps put back together) with hand tools.
AAAS Benchmarks for Science Literacy

Students should practice identifying the parts of things and how one part connects to and affects another. Classrooms can have available a variety of dissected and rearrangeable objects, such as gear trains and toy vehicles and animals.
AAAS Benchmarks for Science Literacy

Follow-up Activities (30 minutes)

Here are some questions that you may ask after viewing the video and facilitating the activities. Jot down some of the participants' comments during this discussion.

- What is your general reaction to the activities and issues you have seen and experienced?
- What special considerations need to be addressed by the teacher, in using science standards as guides to science education?
- What kind of district and administrative support is necessary for a teacher to use the science standards as guides to science education?
- How did the classrooms in the video illustrate:
  curriculum integration?
  classroom management?
  cooperative groups?

Small-Group Planning, by Grade Level (30 minutes)

1. Ask participants to form small groups, by grade level. Distribute Handout 3, "Small-Group Discussion/Planning."
2. Ask participants to use the handout as an outline for their group's discussion, and appoint a spokesperson to record responses and report to the entire group.

Sharing and Concluding Activity (30 minutes)

1. After participants have had sufficient time to respond, invite the spokespersons to share their responses.
2. Ask volunteers to sign up on the sheet you will distribute, if they are interested in being a member of a planning/leadership team.
3. Set a meeting time in the next couple of weeks for the team to meet.

BEST COPY AVAILABLE

HANDOUT 1

Self-Assessment

Answer these questions as well as you can. Be as specific as possible. You'll share your answers with others in the workshop. Use separate sheets of paper, if necessary.

1. I am concerned about elementary science education because:

2. If I were writing standards for science education in the elementary grades, the most important issues I would want to address are:

3. How would science standards improve my effectiveness as a teacher?

4. How would use of the science standards as a guide improve my students' performance?

ASCD
Association for Supervision and Curriculum Development

HANDOUT 2

Reactions to Video

Use this handout to record your reactions to the program.

1. My initial reaction to the video is:

2. The benefits that I see happening through science standards:

3. The schools on the tape have the following characteristics in common with my school:

4. The schools on the tape differ from my school in the following ways:

5. Characteristics that I did not see on the tape that I would like to be present at my school are:

6. I can help my school improve the science program by:

7. I am still very concerned about:

8. I would like to know more about:

9. In the area of science education, my school can be proud of:

ASCD
Association for Supervision and Curriculum Development

HANDOUT 3

Small-Group Discussion/ Planning

Please use the following questions as an outline for your discussion. Appoint a spokesperson to record and report for the group.

As a result of this session:

1. Three important things I've learned are:

2. Two ideas or insights I would like to share with colleagues back home are:

3. One action I will take immediately is:

4. I would like to know more about:

5. I need:

6. I can get what I need by:

7. I can make a difference in my district/school/grade/class by:

ASCD
Association for Supervision and Curriculum Development

BEST COPY AVAILABLE

- The videotape series shows sample lessons that illustrate what science standards actually look like in classroom practice. For teachers and anyone else who wants more information on the lessons depicted, this packet contains lesson plans, background information, suggestions for integration, and other materials.

Land Hermit Crabs

Overview

In this 3rd grade class, students observe the behavior of hermit crabs by performing safe and simple experiments planned by the teacher, and by themselves. In doing so, they are learning about a living creature, and gaining experience in scientific thinking at their own level.

This class had been observing and caring for hermit crabs in the classroom for over a month. They had already become accustomed to handling them, and had learned a great deal about their characteristics. In this lesson, they conducted simple experiments to learn more about the behavior of their pets. By placing the hermit crabs near the weak vinegar and ammonia solutions, children observed the motion of the antennas in response to the smells, and the responses of their hermit crabs. In their own experiments, students tested the responses of the crabs to light, color, motion and food, and began to construct understanding of the design of experiments.

Children can benefit from firsthand experience with a variety of living animals, becoming familiar with their structure and the functions of their different parts. They can observe and compare the animals, their needs, and the ways in which their habitats, behaviors and structural adaptations enable them to meet their needs. Also, caring for classroom animals gives children a sense of responsibility, and concern for living creatures.

Students should have the opportunity to learn about an increasing variety of living organisms, both the familiar and the exotic...
AAAS Benchmarks for Science Literacy

During the elementary grades, children build understanding of biological concepts through direct experience with living things.
Draft, National Science Education Standards

Lesson 1—Observing Hermit Crabs

Problem: What is the hermit crab like?

Materials:
- ✓ hermit crabs (at least one per table, but it is better to have two or three for each table, for comparison purposes, and to ensure that there is at least one that is not too shy to come out and perform)
- ✓ hermit crab habitat (see Habitat, p. 47 of this packet)
- ✓ clear plastic containers (at least one per table)
- ✓ water (not too cold or hot, about 70–85 degrees)

Safety notes: It is safe to hold the hermit crab by its snail shell, and USUALLY safe to allow the crab to crawl in the palm of the hand. However, hermit crabs can give a painful (but not fatal) pinch, if they are afraid of falling. If this happens, holding the hermit crab under cold running water will usually make it let go without harm to the hermit crab. Hermit crabs may also be handled with large salad tongs, if teachers or students are squeamish about handling them.

Although hermit crabs don't have any diseases in common with humans, it is a good practice to have children wash their hands before and after handling any animal.

Procedure:

1. Discuss with the class the animals they have seen. Talk about what they look like, what they do, etc.

2. Tell the class that they will be observing an animal, perhaps one that they haven't seen before. Tell them that the animal is a hermit crab. You may want to use the K–W–L format, writing in columns on the board their answers to the questions, "What do you already Know about hermit crabs?" and "What do you Want to find out?" Make a column labeled, "What we Learned," and maybe one labeled "What we still want to know." Some suggested questions are: How does the hermit crab walk? See? Eat? Smell? How many legs does it have? What are its legs used for?

3. Before distributing the hermit crabs, talk to the class about the importance of humane treatment. It may help to compare their size to the hermit crab's, telling them that they are "giants" to the hermit crab, and asking them to put themselves in the hermit crab's place. Also warn them about the hermit crab's pinchers. (See safety note, above.)

4. Distribute the hermit crabs, either by placing them in the plastic containers on the student tables/desks, or by having one student from each table come to the supply area to get a container and hermit crab(s). Adding a little water, about a half inch (1 centimeter) to the container will help to coax the hermit crabs out of the shell to walk around. Students should not be forced to touch or even be near the hermit crabs, if they are afraid. They usually change their minds and get braver when they observe the reactions of the other children. Use your own judgment about letting the children handle the hermit crabs.

5. When children have observed the hermit crabs at their own tables, exchange the containers, so that they get a chance to observe the variety of hermit crabs, and their snail shells.

6. When all the children have had a chance to observe the hermit crabs, collect them and return them to their "habitat."

7. Gather the children together to discuss their observations, asking questions such as "How does the hermit crab see?" "Are its eyes like ours?" "How are they alike or different?" Also, continue to ask questions that begin with "What do you think . . . ?" "How do you know . . . ?" and "How can we find out?" Were they able to answer any questions from the "What we want to know" list? If so, write them in the column under "What we learned." As shown in the video, some questions need to be answered by looking in a book.

Lesson 2: Hermit crab behavior

(In the video, this lesson and the next were all done in the same morning. There was enough time at the beginning to introduce the lessons with a story about a hermit crab.)

Problem: How do hermit crabs react to odors?

Materials:
Have the following materials set up on the supply table:
- ✓ petri dishes (one per group)
- ✓ cotton swabs (put one or two in each small cup)
- ✓ weak vinegar solution, in small cups (one per table)
- ✓ weak ammonia solution, in small cups (one per table) Use one part ammonia water to 7 parts water.
- ✓ recording sheets and/or lab books

Place the hermit crab habitat on or near the supply table.

Procedure:

1. Tell the students that they will be observing what hermit crabs do when they are placed near things that have a strong odor. Review and emphasize the importance of not hurting their pet. If necessary, discuss the makeup of the groups (groups of 2, 3, or 4).

2. Discuss the procedure, and the materials needed. They will spread each solution on a petri dish, using a cotton swab, and place the

hermit crab near, but not in, the petri dish, and observe its reaction. They should not allow the hermit crab to crawl into the dish.

3. Discuss the class' predictions about how the hermit crabs will react.

4. Assign jobs, including a recorder, a person to come to the supply table to collect the petri dish, and a cup containing the weak vinegar solution and cotton swab. While one student is spreading the solution in the petri dish, others may work with the recorder on listing the materials.

Note: In the video, Lynda's class is accustomed to using a standard format for writing experiments, including problem, materials, procedure, observation, conclusion. (Not every 3rd grader is ready for this kind of writing.) Only one child in each group acts as the recorder, with others helping. In addition, each child has an illustrated lab book, with space for writing observations and stories.

5. When the dish is ready, have the students get their hermit crabs and place them near the petri dish containing the weak vinegar solution.

6. Circulate around the classroom to observe the activity and ask guiding questions, drawing attention to the motion of the hermit crabs' antennas, and their reactions. This is a good time to listen to students' conversations and assess their understanding.

7. When students have had a chance to make their observations, have the materials person return materials to the supply area.

8. Have the students return the hermit crabs to their habitats, then write and/or draw their observations, while you prepare the vinegar for the next activity.

9. Repeat the above procedure, using the vinegar, having students test and record their hermit crabs' responses.

10. Discuss with the students the observations they have made, and the reasons for any conclusions they may have drawn.

Lesson 3—Designing Experiments with Hermit Crabs

Problem: How may we design a test to learn more about hermit crab behavior?

Materials:

- ✓ hermit crabs
- ✓ anything—cardboard, bags, blocks, etc. that children can use to build

1. Give the students a problem: to design a test for the hermit crab that will enable the students to learn more about its behavior and reactions to different conditions. Tell them that they will have a particular time to complete the project, and that all experiments will be done on the same day. (This class made their experiment apparatus over the Memorial Day weekend, from materials they gathered at home.) Emphasize the importance of safety for themselves and the hermit crabs.

2. On the scheduled day, gather the students together to describe their experiments and materials to the class. Ask for comments from the other children.

3. Allow the children to conduct their experiments, circulating throughout the classroom to monitor their procedures, ask questions, and assess their understanding.

4. When the experiments are finished, have the students return the hermit crabs to their habitats, and clean up any materials they have used.

5. Call the children together to discuss the results, asking questions such as, "How did your hermit crab react?" "Why do you think the hermit crab reacted that way?" "What did you learn?" "If you were to do your experiment again, would you do anything differently?"

Organisms have senses that help them detect internal and external cues.
Draft, NRC Science Standards

Students should . . . learn how to communicate their investigations and explanations and those of others.
Draft, NRC Science Standards

Scientific Background

Hermit crabs make good classroom animals because they are relatively easy to care for, do not carry diseases or allergens that affect children, and can be handled, using appropriate precautions.

Hermit crabs are crustaceans, related to lobsters, crayfish, shrimp, and other types of crabs. They belong to the arthropod phylum, because they have an external skeleton and jointed appendages. Besides the crustaceans, other arthropods include the insects, spiders, centipedes, and millipedes. Unlike the other arthropods, only the front parts of hermit crab

bodies are protected by the external skeleton. The abdomen is soft and vulnerable to attack by predators. That is why the hermit crab must find an empty snail shell to protect its abdomen. As the hermit crab grows, it must find larger and larger snail shells in which it can hide.

Each . . . animal has different structures which serve different functions in growth, survival, and reproduction.
Draft, NRC Science Standards

Structure—Crabs are decapods, which means they have 10 legs. In the hermit crab, two pairs are used mainly for walking, and two pairs for holding the crab in the shell. The hermit crab will hold on tightly to its shell. If someone tries to pull it out of its shell, it will allow itself to be pulled apart and killed, rather than let go. The two front legs (chelipeds) are claws, one of which is larger than the other, and is used for protection, climbing, and closing the opening of the seashell in which it lives. The eyes of the hermit crab are on stalks and can move in different directions. The hermit crab has two pairs of antennae, which it uses for smelling, touching, hearing, and possibly for tasting. Perhaps the most obvious feature of the hermit crab is the snail shell, in which it hides to protect its soft abdomen.

The behavior of individual organisms is influenced by internal cues such as hunger and by external cues such as an environmental change.
Draft, NRC Science Standards

Behavior—Land hermit crabs are nocturnal scavengers that travel in large packs (they're not really "hermits") that roam the shorelines at night, looking for food. They are omnivorous, meaning they will eat either plant or animal material. Their natural diet includes fruit, vegetables, seeds, fish, leaves, bark, and decaying wood. They eat by using the smaller cheliped to pass food and water to the mouth, which is located on the underside of the body. They are good climbers, and are often called tree crabs. They can store food and water, and become dormant to survive for a long time, if necessary. They are able to make sounds that may be compared to the sound of a duck quacking, but much quieter.

Growth—Like other arthropods (lobsters, crabs, insects, etc.) that wear their skeletons on the outside, hermit crabs molt, which means they lose their exoskeleton shells as they grow. When they do, their bodies are soft and unprotected, and they have to hide until the new shell forms and hardens. The castoff shell looks just like the hermit crab, including the eyes and antennas, and can be mistaken for a dead hermit crab. Hermit crabs sometimes lose a leg, due to injury. A hermit crab can amputate its own leg if it is injured. A new leg can grow in its place, but it takes a long time, growing a little more with each molt.

Reproduction—The female, after mating, returns to the ocean to lay her eggs. The eggs are carried by the female, attached to three small appendages called swimmerets, located on the underside of the abdomen. Only the females have swimmerets. Larvae develop inside the eggs. After they hatch, they remain with the mother for a few days, and then swim off on

their own. They do not resemble the parents for about a month. After that time, they crawl around on the ocean floor or on the shore to search for shells.

Preparing a Hermit Crab Habitat

Caring for any animal means setting up conditions that are as close as possible to those of its natural habitat. The hermit crabs usually kept as pets are land hermit crabs, which spend most of their lives on land, at the seashore in warm climates such as Florida. Therefore, they need warm temperatures and a humid environment.

Hermit crabs should be kept in a large aquarium, with a base of gravel or sand. A cover on the aquarium will help to prevent escape. A heater, such as a "hot rock," available in pet stores, can be used to maintain a temperature between 70 and 85 degrees (preferably around 85). Spray them and their surroundings with a plant mister every day to provide the necessary humidity, but don't allow the entire terrarium to become wet and sloppy. Provide a dish with commercial hermit crab food, supplemented with cereal, fish, apple, whole wheat bread, etc. Hermit crabs eat very little and are active mostly at night. Uneaten food should be removed before it spoils. Fresh drinking water should always be available in a non-metallic dish, which is shallow enough for the crabs to crawl out of. (They can drown if submerged over an hour.) Add a few sticks of nonresinous wood for them to climb on, but if the aquarium is uncovered, make sure that the sticks aren't so long that they provide a way of escape. A variety of shells should be placed in the aquarium, so that hermit crabs will have new homes to move into as they grow.

Lynda Hammond, the teacher in the video, allows her students to care for the hermit crabs at their desks, if they provide the proper habitats. In this way, students have a chance to observe the hermit crabs closely over a long period of time. Students take them home, with parental permission, at the end of the school year, and often maintain their pets for years.

Organisms have basic needs, air, water and food. Organisms can only survive in environments in which they can meet their needs
Draft, NRC Science Standards

The Covenant

The atmosphere in Lynda's class is unusually calm and accepting, and conducive to creativity and the sharing of ideas. This is due in large part to the school's policy of cooperative learning, and the covenant that Lynda and the class create together at the beginning of the year. See Overhead 2 for a copy of their covenant.

Providing Hands-on Science Materials

Purchasing and replenishing materials for hands-on science lessons can be a big job for a school or district. Lynda's district addresses this problem by using the Elementary Science Program kit service of the Rockland County Board of Cooperative Educational Services (BOCES). BOCES is an intermediate agency of the New York State Education Department, with facilities in various counties throughout the state. It was created to provide shared services for the school districts of those counties. Schools subscribing to the Elementary Science Program can rent kits and receive staff development for their teachers, and are partially reimbursed by the state. Kits are packed in a central location, distributed to member schools four times per year, and are returned to be replenished at the end of each quarter. Most of the materials shown in the hermit crab lessons, including the hermit crabs, were provided in a BOCES Elementary Science Program kit.

Paper Towel Testing

If students themselves participate in scientific investigations that progressively approximate good science, then the picture they come away with will likely be reasonably accurate.
AAAS Benchmarks for Science Literacy

Students should become increasingly comfortable with developing designs and analyzing the product.
AAAS Benchmarks for Science Literacy

Overview

In this lesson, Pat Torpie gives her 3rd grade students an open-ended problem: to test different brands of paper towels to see which one will absorb the most water in 30 seconds. By designing the experiment, and making their own decisions about materials and procedures, students begin to construct understanding of a "fair test." This segment of the video also depicts a situation in which the teacher is the science specialist, teaching the entire science program for the school.

Lesson—Paper Towel Testing

Problem: Which kind of paper towel absorbs the most water in 30 seconds?

Materials:

- ✓ for each group: a plastic or Styrofoam tray
- ✓ 3 or 4 different brands of paper towels, including at least one major, well-advertised brand, and one generic brand. Try to get distinctive patterns and/or textures, so that students can easily distinguish one from the other.
- ✓ a variety of containers, measuring devices, etc. from which children
- ✓ can choose, including measuring cups, spoons, rulers, containers, stirrers, medicine droppers, etc.
- ✓ water

46

Procedure:

1. Discuss with the students the advertising claims made by various products. How can they tell whether the claims are true?
2. Tell them that they are going to devise tests to determine what kind of paper towel absorbs most quickly by seeing how much water each one can pick up in a certain length of time. (In the video, it was necessary for the teacher to set the ground rules, allowing 30 seconds for each test, counting one paper towel as a unit, regardless of its size, and requiring that experiments be conducted on a tray, for easy cleanup.)
3. Review the procedure for designing an experiment: stating the problem, making a prediction, deciding on the materials to be used, making a list, and determining the procedure to be followed.
4. While students are working in their groups to design the experiment, circulate around the classroom to keep students on task, without actually telling them what to do.
5. After each group has decided on the procedure and materials, allow one student from the group to get the supplies, and let the group conduct the experiment they have designed.
6. Circulate around the classroom to monitor progress, ask questions, and assess understanding of the problem and concepts.
7. When students are finished testing, have them clean the desk areas, and return the materials to the supply station.
8. Discuss the results with the class.

   Did all the groups obtain the same results? (probably not)

   What procedures were followed?

   Did any problems arise? How were they resolved?

   What would you do differently if you were to do this test again?

   What did you learn about the properties of paper towels, and their similarities and differences.

   What other characteristics would you like to test?

In everyday life, people are bombarded with claims, claims about products, about how nature or social systems or devices work, about their health and welfare, about what happened in the past and what will occur in the future. These claims are put forth by experts (including scientists), by honest people and charlatans. In responding to this barrage, trying to separate sense from nonsense, knowledge helps.
AAAS Benchmarks for Science Literacy

The idea of a fair test is possible for many students to begin to consider by fourth grade.
Draft, NRC Science Standards

Suggestions for Further Study

- Which paper towel is most economical?
- Can you always judge economy by the number of sheets?
- Do bigger-sized sheets of paper towels always absorb more?
- Would the results be the same if a longer time were allowed for the experiment?

Constructivism

The instructions for this activity are deceptively simple. Few directions are given, because students themselves make up the directions. However, teaching this way requires, for most teachers, a drastic change. In this segment, science specialist Pat Torpie talks about the evolution of her teaching style. In the past, she presented the experiments, and had her students follow step-by-step instructions to reach a predetermined conclusion. Since learning of the constructivist philosophy she presents motivating open-ended problems, and challenges her students to find their own ways of solving them. By having the freedom to try things out, make mistakes, and correct them, children construct their own understanding of scientific concepts and process.

By gaining lots of experience doing science, becoming more sophisticated in conducting investigations, and explaining their findings, students will accumulate a set of concrete experiences on which they can draw to reflect on the process.
AAAS Benchmarks for Science Literacy

From the earliest grades, students should experience science in a form that engages them in the active construction of ideas and explanations and enhances their opportunities to develop the skills of doing science.
Draft, NRC Science Standards

Constructivist teachers know that learning is not passed directly from the lips of the authority to the mind of the student. Instead, learning is constructed, through a variety of experiences in which the learner interacts with materials, events, and other people. The job of the teacher is to motivate these interactions by posing real-life problems which are relevant to students, and will engage them in the construction of their own understanding.

It may not be easy for a teacher to make the transition to this way of thinking and teaching. Teachers need to see themselves as facilitators, rather than dispensers of learning. They need to listen to their students, valuing their thinking, and making sure that others do the same. It may take longer for children to learn in this way, but they will have learned more thoroughly, acquired valuable critical thinking skills, and taken responsibility for their own learning.

Rather than trying to "cover" everything in a textbook or curriculum, the emphasis must be on large, overarching concepts, teaching around themes. ("Less is more.") This may require flexibility, adapting the curriculum in order to be able to respond to student questions, and take advantage of "teachable moments."

Within this context, traditional methods of assessment by multiple choice and other short-answer tests are no longer appropriate. Instead, assessment must be built in to the learning process.

The Science Specialist—Pat Torpie is the science specialist in her school, providing science enrichment for all of the 2nd, 3rd, and 4th grade classes. In addition to her teaching duties, she works with classroom teachers to coordinate her activities with those of the regular science curriculum. She organizes field trips, including overnight camping, and runs an after-school science club, with hands-on projects such as water rockets and hot air balloons.

Overview

Mechanisms

This segment shows two highly motivating hands-on lessons that are part of a unit on simple machines. In the first one, students are challenged to figure out the hidden lever mechanism that controls the motion of cardboard figures, and to devise their own mechanisms. The culminating lesson of the unit, sometimes called "appliance science," engages children in taking apart familiar household appliances and identifying the machines hidden within.

Lesson 1—Hidden Mechanisms

Children should design and make things with simple tools and a variety of materials.
AAAS Benchmarks for Science Literacy

Problem: How can we make a lever mechanism that will move figures in different directions?

Materials:
for the demonstration:

- ✓ sample mechanisms for demonstration, with the levers hidden for each child or group (see illustration B1):
- ✓ a large piece of corrugated cardboard, about 20" × 20"
- ✓ 5–10 one-inch-wide strips cut from corrugated cardboard, about 10–15" long
- ✓ two-legged paper fasteners
- ✓ ballpoint pen or other object for making holes in the cardboard
- ✓ construction paper or drawing paper for the figures

Procedure

1. Show the students how the sample mechanisms move. Ask them to describe what they think is inside, and how they work.

By the end of the 5th grade, students should know that: In something that consists of many parts, the parts usually influence one another.
AAAS, Benchmarks for Science Literacy

2. Tell the students that they will design mechanisms of their own, using the cardboard and fasteners. Show them how to use the ballpoint pens to make holes in the cardboard, and fasten them together with two-legged fasteners to make the pivots.

3. Have the students work in groups of two to four to plan and build their mechanisms.

4. Circulate through the classroom to ask guiding questions, give suggestions, and assess student understanding. Some students may need more guidance than others.

5. When students have finished their projects, ask them to share them with the rest of the class, and let the class guess how they work. Students can turn the mechanisms around to show the levers that work them.

Lesson 2—Appliance Science

This is a culminating activity, to be used only after students have had lots of experience with simple machines.

Problem: What kinds of simple machines and other objects are inside the appliances we use every day?

Materials:

- ✓ discarded appliances, such as tape players, hair dryers, toasters, telephones, etc., at least one for each group (NO TELEVISION SETS—they may contain stored electricity, even when unplugged)
- ✓ a collection of tools, including various sizes of screwdrivers, Phillips head and flat head, pliers, wrenches, sockets, and hammers
- ✓ safety goggles, for yourself and each student

Procedure:

1. Show the students the collection of discarded appliances. Ask them what each one does, and what they expect to find inside. Make a class list of their predictions.

2. Discuss the rules:

   - Wear safety goggles at all times when taking apart appliances.
   - Cut the wires and plugs off all appliances before taking them apart. Appliances should not be plugged in after being dismantled.

- Hammers should only be used with the teacher's permission and supervision.
- Take apart the appliances carefully, piece by piece, without breaking anything. Try to remember where all the parts came from.
- Try to put the appliance back together when you are finished.

3. Also ask the students to keep track of the numbers of screws, bolts, and other objects they find, and to draw a picture of what they see inside the appliance.
4. Allow the students to select the appliances they will dismantle, and to check out tools from the supply table, as needed.
5. Circulate around the classroom, asking guiding questions, and listening to the students' conversations.
6. When students are finished taking apart their appliances (and putting them back together) give each group a bag for the appliance and any loose parts, and place them in the science center for further study.
7. Ask the students to write their reflections on the activity, and report their findings to the class.

Classrooms can have "take-apart" stations where a variety of familiar hardware devices can be taken apart (and perhaps put back together) with hand tools.
AAAS Benchmarks for Science Literacy

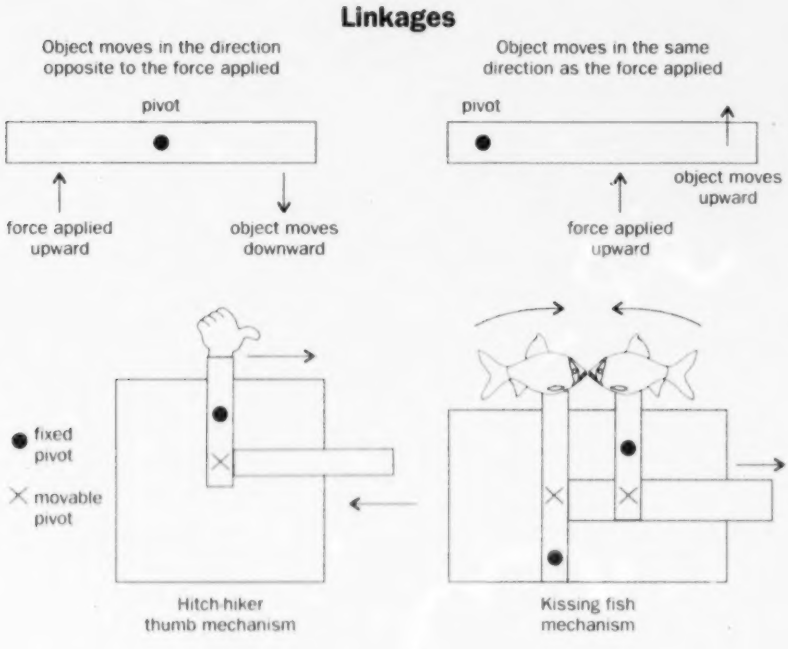
Students should practice identifying the parts of things and how one part connects to and affects another. Classrooms can have available a variety of dissectable and rearrangeable objects, such as gear trains and toy vehicles and animals.
AAAS Benchmarks for Science Literacy

Science Background

Before undertaking the linkages project in the video, Mary's students had learned the characteristics of levers. A lever is a simple machine that consists of a rigid bar or rod that can rotate about a point called a pivot or fulcrum. Common examples of levers are see-saws, tongs, nutcrackers, wheelbarrows, and our own arms and legs.

Levers enable us to change the amount and/or direction of a force. In this activity, it is direction that is important. Depending on the way they are set up, levers can either produce motion in the same direction as the applied force, or in the opposite direction. For instance:

The mechanisms in Mary's class had two kinds of pivots: fixed and movable. The fixed pivots were connected to the larger sheet of cardboard, while the movable pivots were free to move independently of the large sheet.



"Appliance Science"

Taking apart familiar household appliances is a fascinating activity. Children can discover things like gears, pulleys, magnets, levers, screws, and motors, and see how they work together. Appliances can be dismantled as a whole class project, as in the video, or as a learning center activity. The idea is to take apart old appliances to see how they work. Children do not try to fix them. In fact, the first step is to remove the plugs and wires, so that they cannot be plugged in. Mary, the teacher in the video, introduced the subject by using a variety of books and activities on simple machines. Children also learned the names of the tools they would be using. Other advance preparation involves gathering discarded appliances (parents may have some to donate) and setting up a table or desk area with tools. You will need screwdrivers of various sizes—regular and Phillips head, pliers, needle-nose pliers, wrenches, sockets, and wire cutters. You will also need boxes to hold the machines and their parts.

There are a few basic rules:

- Cut the plugs off before dismantling the appliance.
- Wear safety goggles when dismantling machines.
- TVs should not be dismantled, because of the danger of shock from residual electricity. Look out for asbestos in very old appliances.

- Tape players, hair dryers, mixers, clocks, toasters, telephones, coffee pots, and radios are all appropriate.
- Students should try to take the machines apart without breaking them.
- The hammer should be used only with the teacher's permission and supervision.
- Students who bring in tools should label them with their names.

OVERHEADS

OVERHEAD 1

Objectives of the Workshop

At the end of this program, participants will be able to:

- **Explain the significance of documents such as the NRC Science Standards, AAAS Benchmarks for Science Literacy, and science frameworks.**
- **Understand how to design a lesson that incorporates some of the science standards and demonstrates effective management of materials, questioning techniques, integration, and authentic assessment.**
- **Describe the role that elementary science plays in preparing students for life in a technological information age.**
- **Recognize the motivational value of hands-on science activities.**
- **Identify issues and concerns involved in implementing science standards.**
- **Develop a personal or group plan of action related to the science standards.**

ASCD
Association for Supervision and Curriculum Development

OVERHEAD 2

Our Classroom Covenant

**I have a right to be happy and to be treated with kindness in this room.
This means that no one
will laugh at me, ignore me, or
hurt my feelings.**

**I have a right to be myself in this room.
This means that no one will
treat me unfairly because I am
fat or thin,
fast or slow,
boy or girl.**

**I have a right to be safe in this room.
This means that no one will
hit me, kick me,
push me or pinch me.**

**I have a right to hear and be heard in this room.
This means that no one will
yell, scream or shout,
and my opinions and desires will be considered in any plans that we make.**

**I have a right to learn about myself in this room.
This means that I am
free to express my feelings and opinions
without being interrupted or punished.**

ASCD
Association for Supervision and Curriculum Development

OVERHEAD 3

A Look at School Environments—Contrasting Traditional and Constructivist Classrooms

A Look at School Environments

Traditional Classrooms	*Constructivist Classrooms*
Curriculum is presented part to whole, with emphasis on basic skills.	Curriculum is presented whole to part with emphasis on big concepts.
Strict adherence to fixed curriculum is highly valued.	Pursuit of student questions is highly valued.
Curricular activities rely heavily on textbooks and workbooks.	Curricular activities rely heavily on primary sources of data and manipulative materials.
Students are viewed as "blank slates" onto which information is etched by the teacher.	Students are viewed as thinkers with emerging theories about the world.
Teachers generally behave in a didactic manner, disseminating information to students.	Teachers generally behave in an interactive manner, mediating the environment for students.

OVERHEADS

ASCD
Association for Supervision and Curriculum Development

A Look at School Environments

Traditional Classrooms	*Constructivist Classrooms*
Teachers seek the correct answer to validate student learning.	Teachers seek the students' points of view in order to understand students' present conceptions for use in subsequent lessons.
Assessment of student learning is viewed as separate from teaching and occurs almost entirely through testing.	Assessment of student learning is interwoven with teaching and occurs through teacher observations of students at work and through student exhibitions and portfolios.
Students primarily work alone.	Students primarily work in groups.

(Enlarged copy of page 17, *In Search of Understanding: The Case for Constructivist Classrooms*, by Brooks & Brooks, ASCD 1993)

REFERENCES AND RESOURCES

BEST COPY AVAILABLE

References for Science Instruction

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy.* New York: Oxford University Press.

Association for Supervision and Curriculum Development. (1994). *Hands-on Elementary Science* (*Leader's Manual* and *Teacher Sampler*). Alexandria, Va.: ASCD and Technical Education Resource Center (TERC).

Brooks, J.G., and M.G. Brooks. (1993). *In Search of Understanding: The Case for Constructivist Classrooms.* Alexandria, Va.: ASCD.

Lopez, R.E., and J. Tuomi. (May 1995) "Student-Centered Inquiry," *Educational Leadership* 52, 8: 78-79.

The National Center for Improving Science Education. (1989) *Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction.* Washington, D.C.: The NETWORK, Inc.

National Research Council. (November 1994). *National Science Education Standards, Draft for Response and Comment.* Washington, D.C.: National Academy of Sciences. (Final version, with many more examples and vignettes, expected December 1995. Call National Academy Press at 1-800-624-6242. Estimated price: $19.95).

New York State Education Department. (1994). *Framework for Mathematics, Science and Technology.* Albany: Author.

Rutherford, F.J., and A. Ahlgren. (1990). *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology.* Washington, D.C.: American Association for the Advancement of Science; New York: Oxford University Press.

Willis, S. (Summer 1995). "Reinventing Science Education." *Curriculum Update*, 1–8. (Alexandria, Va.: Association for Supervision and Curriculum Development).

References for Lessons Section

Adkins, J. (1980). *Moving Heavy Things.* Boston: Sandpiper Books, Houghton Mifflin.

Burnie, D. (1991). *Machines and How They Work.* London: Dorling Kindersley.

Jennings, T. (1993). *How Things Work: Cranes, Dump Trucks, Bulldozers and Other Building Machines.* New York: Griesewood and Dempsey.

Lampton, C. (1991). *Seesaws, Nutcrackers and Brooms—Simple Machines That Are Really Levers.* Brookfield, Conn.: The Millbrook Press, A Gateway Book.

Pohl, K. (1987). *Hermit Crabs.* Milwaukee: Raintree Publishers.

Sneider, C.I., and J. Barber. (1987). "Paper Towel Testing." In *Great Explorations in Math and Science*. Berkeley: Regents of the University of California, Lawrence Hall of Science.

Van Cleave, J. (1993). *Janice Van Cleave's Machines.* New York: Wiley.

ASCD
ASSOCIATION FOR SUPERVISION AND CURRICULUM DEVELOPMENT
SUMMER 1995 • 1250 N. Pitt Street, Alexandria, VA 22314-1453 (703) 549-9110

CURRICULUM UPDATE

Reinventing Science Education

Reformers Promote Hands-On, Inquiry-Based Learning

In Lisa Nyberg's classroom at Brattain Elementary School in Springfield, Ore., 3rd and 4th graders are learning about simple machines. The classroom is a flurry of activity, as children take apart broken toasters and other household appliances, trying to identify the simple machines within. Students examine and test the mechanical workings intently, discussing their ideas with their partners. A child disassembling a tape recorder forms the theory that pushing a certain button works a switch. Another child is consulting the resource books scattered around the room, searching the index of *How Things Work* for "vacuum cleaners." When the children discover inexplicable components—such as electrical circuits and computer chips—they are eager to learn more.

Across the country, in Michele Bartlett's earth science class at Rundlett Junior High School in Concord, N.H., 8th grade students are participating in an international ozone monitoring project. Using filter-paper badges, students collect smog data locally and then share their findings via the Internet with students at 80 other schools around the world. Bartlett's students also graph and analyze the data. In the process, they learn vocabulary such as "nitrous oxide" and "parts per billion," without having to resort to rote memorization. Students also submit their data to the Air Quality Board, the governor, and the National Student Research Center. Because they care about air quality, and because they are collecting real data to be shared with others, students take their work seriously.

LINDA ARMSTRONG

Giving students experiences with real phenomena is central to the reform agenda.

If these students had been born only a few years earlier, their experiences in learning science might have been starkly different. Science education has traditionally followed the "teaching by telling" approach. Teachers have relied heavily on textbooks and lectures to convey large quantities of information, and students have been expected to memorize reams of facts and terminology. Hands-on experiences have typically been limited to "cookbook labs" with outcomes known in advance, not real investigations. In most classrooms, science has been presented as an inert body of knowledge to be assimilated, rather than a process of inquiry and a way to make sense of our world.

The traditional "telling" approach has allowed science teachers to cover a great many topics. But the quality of student learning that it has yielded has proven disappointing, experts in the field say. Many students can parrot what they've been taught, but their understanding of science concepts is often seriously flawed. Students' prior misconceptions, for example, stubbornly resist change.

Even on standardized tests, which emphasize recall over reasoning, student achievement has been lackluster. According to the most recent data from the National Assessment of Educational Progress, "Compared to 1969–70, average [science] achievement in 1992 was higher at age 9, essentially the same at age 13, and lower at age 17."

Willis, S. (Summer 1995). "Reinventing Science Education." *Curriculum Update*, 1–8.

Perhaps worse, the "telling" approach bores and alienates many students, who stop taking science courses as soon as possible. As a cohort of students progresses through high school, the number enrolled in science classes drops by roughly half each year, experts say. And the students who typically stick with science courses and succeed in them—students who are highly verbal and have good memories—do not necessarily make the best scientists.

Faced with these problems, the science education community is working zealously to reform itself. Major organizations—such as the National Science Foundation (NSF), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and the National Academy of Sciences—are vigorously promoting the kinds of hands-on, inquiry-based activities described at the beginning of this article.

Reformers have set forth, in detail, a new vision for science education. Strong themes in the reform literature include the following:

- Learning of concepts should be emphasized over memorization of terms and facts.
- Students should have ample opportunities for hands-on learning. Concrete experiences with actual phenomena should precede more abstract lessons.
- Science instruction should be inquiry-based, at least in part. Students should have opportunities to pose their own questions, design and pursue their own investigations, analyze data, and present their findings.
- Teachers should explain concepts thoroughly before introducing the terminology associated with them, to ensure real understanding rather than parroting.
- Teachers should teach fewer concepts, in greater depth, rather than covering a great many topics superficially. ("Less is more.")

A Snapshot of the Field

How does science education play out on a day-to-day basis, in classrooms across the United States? Findings from the 1993 National Survey of Science and Mathematical Education, conducted by Horizon Research, Inc., with funding from the National Science Foundation, shed light on this question. The survey gathered data from approximately 6,000 U.S. teachers of math and science in grades 1–12 about their beliefs and practices. It also gathered data from department heads and lead teachers about their schools' science programs. Some illuminating findings follow.

Science Instruction

- Although use of hands-on activities has increased since the mid-1980s, science teachers still rely heavily on lectures and textbooks.
- The vast majority of science classes use one or more commercially published textbooks or programs, including 95 percent of middle and high school science classes. At the elementary level, 75 percent of science classes use published textbooks or programs, down from 86 percent in 1986.
- Looking across all science classes, the largest proportion of class time is devoted to lecture and discussion (38 percent), followed by hands-on or laboratory work (23 percent), individual seatwork (19 percent), and nonlaboratory small-group work (10 percent), with the remaining 10 percent of time spent on noninstructional activities.
- Sixty percent of high school science and math classes listen and take notes during presentations by the teacher on a daily basis; 94 percent do so at least once a week.
- More than 60 percent of high school science classes never take field trips, 54 percent never use computers, and 43 percent never work in class on science projects that last at least a week.

Teachers' Goals

- According to teacher reports, the most heavily emphasized objectives in science classes are learning basic science concepts (heavily emphasized in 83 percent of science classes overall), increasing awareness of the importance of science in daily life (77 percent), and developing problem-solving and inquiry skills (74 percent).
- Approximately 20 percent of science classes in each grade range put heavy emphasis on preparing students for standardized tests.
- Teachers in classes with high proportions of minority students are more likely than others to emphasize preparing students for standardized tests, and less likely to aim toward preparing students for further study in science and math.

Time Devoted to Science

- In elementary classes, an average of only about one-half hour per day is spent on science instruction. This figure has increased slightly over the past 15 years.
- Students are typically required to take two years of science in high school.

Diversity Issues

- Non-Asian minority students are particularly likely to "drop out" of science and math course taking.
- The proportion of science and math teachers who are themselves members of minority groups is very low—only about 11 percent in the elementary and middle grades and 7 percent at the high school level, at a time when roughly 30 percent of students belong to minority groups.

Equipment Needs

- Many science teachers indicated that certain kinds of equipment they need are unavailable. The most frequently cited needs were for running water, electrical outlets, gas for burners, and hoods or air hoses in laboratories, as well as videodiscs and CD-ROM players.

Adapted from *A Profile of Science and Mathematics Education in the United States: 1993*, by Iris Weiss of Horizon Research, Inc., 111 Cloister Court, Ste. 220, Chapel Hill, NC 27514-2296. ●

JOHN McNAMARA

Hands-on approaches will attract a broader range of students to science courses, reformers believe.

- Students should have opportunities to *apply* science knowledge and to make connections between what they learn and their everyday lives.
- Teachers should build on students' prior understandings and prod them to rethink their misconceptions.
- All students should become science literate, not just the college-bound. Schools should prepare science-literate citizens, not just future scientists.
- Educators should begin to integrate the various science disciplines (biology, chemistry, physics), as well as integrating science with other subject areas.

The "overarching theme" of these reform ideas is constructivism, says Dennis Cheek, who coordinates mathematics, science, and technology for the Rhode Island department of education. The focus is on "allowing students to make meaning for themselves" through active learning experiences, rather than just barraging them with information.

These reform ideas are "absolutely vital," says Anthea Maton, a science education consultant from Oklahoma City. There's a big difference between teaching from the textbook and making sure students grasp concepts, she asserts. Students who only *know* the science they're learning and students who truly *understand* it are "poles apart."

Maton cites the example of a class she observed where a student incorrectly used the term *inertia* instead of *momentum*. If teachers introduce these terms without having students explore and discuss the associated concepts thoroughly, she says, students' understanding of the terms may be limited to "if something moves, it has it."

Inquiry-based learning yields deeper understanding because it focuses on the question "How do we know?" says Gerhard Salinger, a program director at the National Science Foundation. Although teachers can simply *tell* students facts—for example, that the earth has seasons because it rotates on a tilted axis—students will understand (and remember) such concepts better if they explore why we believe them to be true. Experimenting with a flashlight and tennis balls, he suggests, can help students truly understand what causes the seasons—and gives the teacher an opportunity to confront the misconception that, during winter, the entire earth moves farther from the sun.

These reform ideas are not new; experts in the field readily admit. Yet, from his visits to classrooms, Cheek has found "there's still an awful lot of 'chalk and talk' going on." Many teachers still place more emphasis on maintaining "control and quiet" than on using active, hands-on approaches that help students gain real understanding. Implementation of these ideas has a long way to go.

Major Reform Efforts

Several massive reform efforts are aimed at changing that situation. The National Science Foundation, for example, is funding statewide systemic initiatives to promote reform. Other high-profile efforts include NSTA's Scope, Sequence, and Coordination project, AAAS's Project 2061, and the new National Science Education Standards project.

Scope, Sequence and Coordination of Secondary School Science (SS&C) is a reform effort of the National Science Teachers Association (NSTA). SS&C recommends that all students study each science discipline—biology, chemistry, physics, earth and space science—every year for six years (in grades 7–12).

This approach is a radical change from the prevailing "layer-cake curriculum," in which students study earth science in 9th grade, biology in 10th grade, chemistry in 11th grade, and physics in 12th grade. (More than half of all students don't take a science course after 10th grade, and only 19 percent take a course in physics, according to NSTA literature.) The SS&C approach spreads out the study of each science discipline over several years. It also features hands-on, inquiry-based instruction.

When students study each science discipline beginning in the middle grades, courses like chemistry and physics don't seem so "foreign" to them when they are juniors and seniors, says Thomas Sachse, executive director of the California Science Project, a statewide staff development network. And because students learn these disciplines gradually, without complex math at first, they develop "an affinity, not a fear" for them, he adds.

SS&C is "trying to provide a substantial level of understanding [in each science discipline] for all students, in a society where people believe that most students can't learn it," says Bill Aldridge, NSTA's executive director. Most people, including science educators, sincerely believe that science at certain in-depth levels can't be learned by everyone, he charges. Yet the evidence against this belief—from countries that teach demanding science to a far greater proportion of students than the United States does—is "overwhelming," he says.

Typical science courses put "all the abstractions at the beginning" and emphasize the memorization of facts and processes—an approach that "basically sorts people out," Aldridge says. By contrast, SS&C modifies the curriculum in accordance with the research on how students learn. As a result, "essentially all kids can learn it."

Since 1990, SS&C has been implemented at the middle-school level at six pilot sites. Now, a newly launched study of 15 high schools implementing SS&C will "put it to the test," Aldridge says. He hopes the independent evaluation will show "dramatic" results, especially for minority students. Just showing a positive effect will not spur broad-scale change, he believes.

Project 2061, a long-term reform initiative of the American Association for the Advancement of Science (AAAS), addresses science, mathematics, and technology, says Jo Ellen Roseman, the Project's curriculum director. It focuses on the curriculum, because curriculum is "central to the reform effort." The Project's philosophy is set forth in two major publications, *Project 2061: Science for*

All Americans and *Benchmarks for Science Literacy*.

Science for All Americans, published in 1989, defines "a clear set of adult literacy goals in science, mathematics, and technology for everyone," Roseman explains. *Benchmarks for Scientific Literacy*, released in 1993, suggests concepts to introduce at grades 2, 5, 8, and 12 that would constitute "reasonable progress" toward the literacy goals. Where the benchmarks and the draft national standards for science education overlap (natural science and technology), they are "overwhelmingly the same," Roseman says, and thus mutually reinforcing. (For more on the national standards, see box, below.)

According to *Science for All Americans*, Project 2061 envisions a science curriculum in which

• the amount of detail that students are expected to retain is considerably less than in traditional courses, so that important concepts can be explored in some depth. Ideas and thinking skills are emphasized at the expense of specialized vocabulary and memorized procedures.

• boundaries between traditional subject-matter categories are softened and links are emphasized, so that students will appreciate connections among ideas.

• some topics rarely found in school curriculums are addressed, including the nature of the scientific enterprise, important episodes in the history of science and technology, and the major conceptual themes that run through almost all science thinking.

Project 2061 recognizes that curriculum reform is "necessary but far from sufficient" to transform science education, Roseman says. To support other aspects of reform, AAAS is producing computer disks of descriptions of recommended professional development resources and teaching materials. (The former will be available by

National Standards Seen as a Catalyst for Reform

Science, like many other subject areas, will soon have a set of national standards to bolster the efforts of reformers. Developed by the National Research Council (an agency of the National Academy of Sciences and the National Academy of Engineering), the *National Science Education Standards* have been widely disseminated in draft form. The final version is expected to be published this fall.

Unlike some similar efforts in other subject areas, the science standards take a systemic approach. Beyond spelling out important science content, they describe the kind of teaching, professional development, and assessment the field should provide. The draft document also includes "program standards"—criteria for judging school science programs—and "system standards," which address resources and coordination at the state and federal levels.

Not surprisingly, the science standards promote the major themes in the reform literature. The standards document states the following principles, among others, at the outset:

• All students should have the opportunity to attain higher levels of scientific literacy than they do currently.

• All students will learn all science in the content standards.

• All students will develop an understanding of science that enables them to use their knowledge in personal, social, and historical contexts.

• Learning science is an active process.

• For all students to understand more science, less emphasis must be given to some science content and more resources must be devoted to science education.

Development of the standards began in 1992, with broad input from scientists and science educators. The fourth and last round of review began in December 1994. Close to 40,000 copies of the draft document have been distributed, half to individuals and half to focus groups of teachers, professors, businesspeople, and scientists.

"I am relieved to say that most of the responses are very positive," reports Angelo Collins, director of the National Science Education Standards Project. One complaint some reviewers have made, however, is that the draft document is too long. "No one has suggested something to take out, though," Collins notes wryly. Other reviewers have criticized the standards for failing to capture adequately the *quantitative* aspect of science—a concern that will prompt some revisions, Collins says.

The content standards focus on fundamental concepts—the "big ideas" such as motion, force, matter, energy, evolution, and genetics—rather than bogging down in numerous topics, factoids, and technical words, says Rodger Bybee, who served as chair of the working group on science content standards. Bybee is associate director of the Biological Sciences Curriculum Study (BSCS).

The content standards also attempt to broaden science learning beyond a narrow focus on life, earth, and physical sciences, Bybee says. Therefore, they include several other categories as well: science and technology, science in personal and social perspectives, history and nature of science, unifying concepts and processes, and science as inquiry.

According to the standards document, inquiry "involves making observations, posing questions, examining books and other sources of information to see what is already known, planning investigations, reviewing what is already known in light of experimental evidence, proposing answers and explanations, and communicating the results."

The content standards represent fundamental concepts that *all* students should grasp, Bybee says. "We're focusing on the question, 'What should all citizens know and be able to do?' not 'What do students need to know to get into graduate school?' "

The standards are "silent" on the question of how the curriculum should be organized, Bybee points out. They do not pass judgment on the layer-cake curriculum, interdisciplinary approaches, or AP courses, for example. States and districts must determine what form the curriculum should take, he says.

Teaching Standards

Although the science standards also address teaching, they *don't* say, "This is the one way to teach," notes Karen Worth, who served as chair of the working group on science teaching standards. Worth is a senior associate at the Education Development Center and a faculty member in the graduate school of education at Wheelock College.

the end of this year; the latter, by late 1996, Roseman predicts.) Two other publications, *Designs for Science Literacy* and *Blueprints for Reform*, will help educators design K–12 science curriculums and pursue systemic reform, respectively.

What Teachers Need

The national science organizations are calling for reform, and teachers are listening. Do they like what they hear?

Teachers, as a group, have mixed feelings about the reform agenda (see box, p. 6). Those in the upper grades tend to be more resistant. The teachers interviewed for this article—all of whom have received Presidential Awards for Excellence in science—were enthusiastic about the reform ideas but described a variety of obstacles to implementing them.

To take a hands-on approach, teachers "constantly have to put together materials and activities," says Alfred Benbenek, who teaches 5th grade at Holt Elementary School in Whitman, Mass. Given small budgets for science materials, teachers have to "beg, borrow, and steal" materials such as cups, zip-lock bags, wires, batteries, and aluminum foil, he says. Because these things wear out, teachers are in constant need of them.

Teachers are eager to do hands-on activities, says Jane Carey, who teaches 2nd grade at Lancashire Elementary School in Wilmington, Del. Teachers are held back, however, by lack of direction about what to do, lack of materials (without scrounging), and lack of training, which makes them "hesitant to jump in."

Carey teaches a unit on "sinking and floating" in which students test a variety of objects to see whether they sink or float, then try to turn a "sinker" into a "floater" and vice versa. The class makes a chart of materials and their properties. Then students apply what

Because the standards promote science as inquiry, they ask teachers to help students become inquirers who learn basic concepts in the context of investigations. Worth acknowledges that this role will not appeal to all teachers. "There are teachers out there who still do not believe philosophically in teaching for understanding rather than [dispensing] information," she says. "If you're in the 'they-really-should-know-these-facts' camp, you won't want to do this." Teachers who want students to construct their own understandings, on the other hand, will find the standards "an important validation," she believes. These teachers "tend to be viewed as the fringe," she says. "Now they will be validated as the center."

The bottom-line message of the assessment standards is that educators should collect information about what students understand for a *variety* of purposes—not just to assign grades, says Audrey Champagne, who served as chair of the working group on science assessment standards. Champagne is a professor of chemistry and education at the University of Albany (SUNY).

The new emphasis on inquiry and reasoning skills poses a challenge for assessment, she notes. It's relatively easy to assess whether a student can use a balance to measure mass, for example—it's harder to assess whether the student can figure out that she *needs* to use a balance. Yet both kinds of abilities are important to assess.

Nothing New?

"To some degree, you could say there's nothing new in the standards," says Harold Pratt, who worked on the standards development team for more than two years. A former director of curriculum in Jefferson County, Colo., Pratt now directs an elementary science program for BSCS. The ideas reflected in the standards have been widely accepted in the field for many years, Pratt maintains. Yet "they are far from being implemented," he says. Implementation has been "our Waterloo."

The standards should be neither slavishly followed nor dismissed out of hand, Worth says. "This is not a perfect document, and it should not be followed perfectly—but it should be seriously considered."

The response of many teachers to the standards, however, is "You must be kidding," Worth concedes. Teachers' resistance is not so much a reaction to the philosophy embodied in the standards as to the fact that assessments and resources are not yet aligned with that philosophy. Even some teachers who fully endorse the standards say, "I'm not going to touch these until the rest of the world agrees and provides the resources we need for implementation." Worth calls this attitude "a well-founded cynicism."

Educators should not expect that teachers will pick up the standards and use them directly, Pratt says. "This is not a document that tells you what to do in your classroom tomorrow." The standards are "not a how-to document," Worth agrees. Instead, they are "a guide for decision making"—a set of criteria against which to weigh policy decisions, from the school level to the national level.

Perhaps unfortunately, the scope of the national standards does not, for the most part, extend to higher education, Pratt notes. "That piece is yet to be done—and it's an important part of the system."

The standards are one strategy for moving reform forward—not a panacea, Pratt says. But they will serve as "a catalyst for improvement," he believes. "They will focus our attention." Science educators should get acquainted with the standards and use them as a focus of dialogue and discussion, he advises.

Although the standards document is only in draft form, "the signs are that it's already had a big impact," Collins says. The standards are exerting an influence on state curriculum frameworks, textbook publishers, and professional development offerings, she says. The major organizations in science education are all promoting their implementation, she adds. For example, NSTA has already published *A High School Framework for National Science Education Standards* to help educators create programs based on the standards.

"The harder task lies before us," Bybee cautions. "It was relatively easy to develop the standards. But translating them into programs to help all students achieve higher levels of scientific literacy will be a tremendous task," he says. The "scaling up" will require a concerted, national effort. States and districts will have to devote resources to the endeavor, as will the U.S. Department of Education, the National Science Foundation, organizations such as NASA, and private foundations. "It's their move now." ●

The final version of the standards, anticipated next fall, will be sold by National Academy Press. For more information, contact the National Science Education Standards Project, 2101 Constitution Ave., N.W., HA 486, Washington, DC 20418, (tel.) 202-334-1399.

they've learned by creating a classroom aquarium. "If teachers had the time and resources," more ideas like this would flourish, Carey says.

Judy Morlan, who teaches 6th grade at Brownell Middle School in Grosse Pointe Farms, Mich., finds it "very difficult" to put constructivist principles into practice in her science teaching. She is frustrated by "a tightly packed curriculum" that she is held closely to. Because she must cover all the objectives, Morlan can't take the time to teach certain topics in depth, as she would like to do. In addition, trying to identify the misconceptions of a classful of children, and then working to change them, is very time-consuming.

"I feel like I'm in the middle," she says, because she is forced to compromise. "I'm a part-way person."

Morlan uses active learning "to make an impression on kids with the important things." For example, she has her students pace out the relative distance of the planets from the sun. "They respond to this sort of thing," she reports. She feels her efforts have been worthwhile when, for instance, a student exclaims, "Oh, my gosh—I didn't realize Pluto was *that* far from the sun!"

High school teachers are reluctant to change because they still feel accountable to colleges and universities, says Margo Murphy, who teaches 9th-grade environmental science at Georges Valley High School in Thomaston, Maine. Although Murphy herself doesn't teach from a textbook, most high school science is textbook-driven, she says. To create another kind of course demands "an enormous amount of work" from a teacher. It takes "a huge amount of time to convert" to an inquiry-based approach, she says.

Naturally, given these challenges, reformers are calling for more professional development for teachers of science. Teacher training is a big component of reform proposals, says Maton. "Nobody is advocating just *telling* teachers to teach this way."

Reform should *focus* on teacher education—both preservice and inservice, says Marvin Druger, chair of science teaching at Syracuse University and president of NSTA. "That's where the action should be." Many reformers are urging that undergraduate science courses become inquiry-based as well. Future teachers who have learned science in 300-seat lecture halls will not know how to foster active learning, they assert.

Teachers' Attitudes Toward Reform

Do teachers embrace the reforms in science education that national organizations are advocating? The 1993 National Survey of Science and Mathematical Education provides some insights. Conducted by Horizon Research, Inc., with funding from the National Science Foundation, the survey asked approximately 6,000 U.S. teachers of math and science in grades 1–12 about their training, pedagogical beliefs, and instructional practices. Here are some highlights from the findings:

Teachers Support Some Reform Ideas . . .

- Nearly all teachers believe hands-on activities should be part of science instruction.
- Most teachers believe that science instruction should provide students with concrete experiences before exposing them to abstract treatments. About 84 percent of high school teachers, and more than 90 percent of teachers at other levels, hold this view.
- Most teachers believe that students learn best when they study science in the context of personal or social applications. More than 90 percent of teachers at the elementary and middle school levels hold this view, as do 86 percent of teachers at the high school level.
- Most teachers support the use of cooperative learning in science classes. More than 80 percent of teachers at the high school level, and more than 90 percent of teachers at other levels, hold this view.

. . . But Resist Others

- Teachers are divided on the idea of emphasizing "depth over breadth." Only about 70 percent of elementary and middle grade teachers, and fewer than 60 percent of high school teachers, agree that science and math instruction should provide deeper coverage of fewer concepts.
- Many teachers resist the advice of reformers to teach science concepts *before* teaching the terminology associated with those concepts. Nearly one-third of teachers in grades 1–4, increasing to more than half of high school science teachers, indicated that "it is important for students to learn basic scientific terms and formulas before learning underlying concepts and principles."
- Although the reform literature calls for de-emphasizing factual learning in science, many teachers report that they emphasize this objective in science classes. Half of elementary science classes, and nearly 2 out of 3 in the middle and high school grades, put heavy emphasis on learning "important terms and facts in science."
- Many teachers doubt that heterogeneous grouping is the way to ensure success for all students. Roughly 3 in 10 teachers of grades 1–4 believe that students learn science and math best when grouped with peers of similar abilities. At the high school level, more than 7 out of 10 teachers hold this view.
- Although reform advocates tend to be critical of science textbooks, most science teachers are pleased with the quality of their textbooks. About 3 out of 4 teachers rate their science textbooks "good" or better.

Attitudes Differ by Grade Level

- Elementary teachers tend to be confident in their ability to use reform-oriented strategies such as cooperative learning. However, many do not feel confident in their ability to teach a number of elementary science content areas.
- High school teachers are more likely to have extensive preparation in their subjects, but they are less supportive of reform-oriented teaching techniques, less confident in their ability to use them, and less likely to do so in their classrooms.

Adapted from *A Profile of Science and Mathematics Education in the United States: 1993*, by Iris Weiss of Horizon Research, Inc., 111 Cloister Court, Ste. 220, Chapel Hill, NC 27514-2296. ●

Science courses have been too abstract and too mathematical from the outset, reformers charge.

In the reform literature, "textbook-driven" has become a pejorative term. Reformers of science education have criticized textbooks for abetting the "teaching by telling" approach.

Science texts in the United States differ from those used in other countries, says Senta Raizen, director of the National Center for Improving Science Education. U.S. textbooks "treat many topics in a scattershot fashion," whereas those in other countries treat fewer topics, in greater depth, and include far less review.

But U.S. texts are beginning to change, Raizen says. Textbook publishers try to follow state guidelines, she notes. "They're not nasties." But they can't prescribe how motivated teachers will be to encourage students' own investigations rather than lecturing from the textbook, she adds.

One 11th-grade textbook that anticipated the reform movement is *Chemistry in the Community*, developed in 1982 by the American Chemical Society. Now in its third edition, the book is "still considered rather nouveau," says Sylvia Ware, director of the Society's education division.

Chemistry in the Community was designed to correct the "mismatch" between chemistry instruction and students, Ware says. Most high-school chemistry serves best as an introduction for those who intend to earn a bachelor's degree in the subject—"but of course most students won't do this," she points out. Instruction is too abstract and too mathematical, Ware charges. "Chemistry doesn't have to be a quantitative discipline from Day One."

Unlike a traditional text, *Chemistry in the Community* examines issues in the community, to teach "chemistry for citizenship." The book is designed around eight issues: water needs, conserving chemical resources, petroleum, food, nuclear issues, air, health, and industry and its role in society.

Students using the text make lots of decisions and apply chemical knowledge, Ware says. In the first unit, for example, a scenario describes a "fish kill" in an imaginary river. Students investigate why the fish died, then hold a town meeting, where the facts come out. Then they must decide how to handle the problem.

"We're trying to rehabilitate the utilitarian," Ware says. "Knowledge can be useful—that's not a negative! If knowledge were only abstract, we'd never have got out of caves," she jokes.

Going Too Far?

Despite widespread enthusiasm for reform, some science educators fear that reform ideas may be taken to extremes.

"There seems to be a [misconception] that all science at all grade levels should be learned through inquiry," says Audrey Champagne, a professor of chemistry and education at the University of Albany (SUNY). Champagne finds this view too one-sided. In the early grades, inquiry-based learning can help students develop knowledge and reasoning skills that will enable them to learn in more traditional ways ("book learning") in the upper grades, she believes.

The heavy emphasis on inquiry may be an overreaction to the current overemphasis on facts, Champagne says. "Education in the United States is characterized by pendulum swings to the extreme."

Inquiry-based instruction is "a good idea in moderation," says David Haury, director of the ERIC Clearinghouse for Science, Mathematics, and Environmental Education. As students, "we all benefit from a *mixture* of experiences."

In today's climate of reform, there is a readiness to denigrate textbooks and lectures, Haury says. But when students' curiosity is aroused, they are receptive to reading or listening. And if students are to become science literate in 12 years of schooling, "some things must be told to them." Therefore, teachers should seek a "happy balance," Haury advises. "You don't have to throw away one [approach] to do the other."

Haury also has concerns about the "less is more" philosophy. Teachers embrace the idea, he says, but they are uncomfortable with having to defend the practice. Teachers are placed in an awkward position when they must respond to administrators or parents who ask, "Why aren't you teaching this formula or that set of facts?"

Paring down the curriculum in keeping with the "less is more" philosophy ought *not* to be done on an individual-teacher basis, says Carolee Matsumoto of the Education Development Center. It's "risky" for teachers to take a stand on their own; they are too vulnerable to attack. Instead, the school or district should develop a scope and sequence with input from science experts, teachers, parents, and others, she says.

Some science teachers are uncomfortable with the notion of de-emphasizing facts and terms. Paul Pomeroy, who teaches 12th-grade physics at Archmere Academy in Claymont, Del., believes the reform ideas are "incredibly good in many ways." But he also thinks the heavy emphasis on teaching concepts is "a misguided notion." What started as a push to *include* hands-on activities and opportunities to conceptualize is being "misconstrued by many as the only good way to teach science," he says.

Pomeroy agrees with reformers that "memorizing and spitting stuff back is horrible science." But students still need to know

terms, facts, and how to compute, he says. And "there are times you have to get into the theory and muck through it."

College-bound students still need to develop the skill to "regurgitate" information, says C. Ford Morishita, who teaches biology at Clackamas High School in Milwaukie, Ore. Teachers of Advanced Placement (AP) courses *must* emphasize coverage and teach prescribed labs, he adds. "You can't cut content or you're cutting students' throats on AP exams."

Raizen also advocates using a mix of instructional strategies. "I'm someone who wants to make sure we don't throw out older styles of teaching," she says. However, most classes are still textbook- and lecture-oriented, she points out. "We're far from having the pendulum swing too far—yet."

The reform notion of extending science instruction to a much broader range of students also raises concerns.

Schools can't teach just a "literacy curriculum," says Morishita. "Bright kids need another level of opportunity." He worries that schools might phase out advanced single-discipline science classes and research opportunities. "We can't do 'science for all' at the expense of the high achievers," he says.

Pomeroy also fears that "in making sure every student gets some science, we may sell the top third of students short," by "diminishing the intensity" of their instruction. He is disturbed by the prevalent attitude that bright students will thrive, regardless of their school experiences. "A good student needs to be pushed too—and farther," he says.

"Science for all" is the subject of "a raging argument," Salinger of NSF says. One way of teaching that challenges *all* students—even "the really bright kids"—is to pose open-ended "design problems," he says. For example, a teacher could ask students to design a container to get a baked potato home hot from a fast-food restaurant. This problem requires students to set a standard for what "hot" is, measure the thermoconductivity of various materials, consider structural rigidity, and address environmental concerns. Different students could be encouraged to design their solutions under different sets of constraints, depending on their ability, Salinger adds.

Moving Beyond Experience

The reform movement in science education is promoting many very good ideas that make logical sense, Haury says. But how do educators actually put them into practice? "None of us have experienced it," he says of the new vision of active learning. "Trying to get large communities of people to think beyond the boundaries of their own experience—that's the challenge." ●

Resources

The following organizations can provide resources for improving science education.

American Association for the Advancement of Science, 1333 H St., N.W., Washington, DC 20005; (tel.) 202-326-6666; (fax) 202-842-5196.

National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000; (tel.) 703-243-7100; (fax) 703-243-7177.

ERIC Clearinghouse for Science, Mathematics, and Environmental Education, The Ohio State University, ERIC/CSMEE, 1929 Kenny Rd., Columbus, OH 43210-1080; (tel.) 614-292-6717.

National Science Resources Center, Arts and Industries Bldg., Room 1201, Smithsonian Institution, Washington, DC 20560; (tel.) 202-357-2555; (fax) 202-786-2028. The NSRC collects and disseminates information about exemplary teaching resources, develops innovative curriculum materials, and sponsors outreach activities to help school districts develop and sustain hands-on science programs.

Eisenhower National Clearinghouse for Mathematics and Science Education, The Ohio State University, 1929 Kenny Rd., Columbus, OH 43210-1079; (tel.) 614-292-7784; E-mail: info@enc.org. The Clearinghouse maintains an up-to-date and comprehensive listing of mathematics and science curriculum materials.

National Association for Science, Technology, and Society (STS), Pennsylvania State University, 133 Willard Bldg., University Park, PA 16802; (tel.) 814-865-3044; (fax) 814-865-3047. NASTS promotes examination of the impact of science and technology on society and the environment.

National Center for Improving Science Education, 2000 L St., N.W., Ste. 603, Washington, DC 20036; (tel.) 202-467-0652; (fax) 202-467-0659; BITNET: sentar@gwuvm.gwu.edu. NCISE provides a range of products and services to policymakers and practitioners who are working to strengthen science education.

Biological Sciences Curriculum Study, Pike's Peak Research Park, 5415 Mark Dabling Blvd., Colorado Springs, CO 80918; (tel.) 719-531-5550. BSCS is a nonprofit organization that designs curriculums in the sciences.

Education Development Center, 55 Chapel St., Newton, MA 02158; (tel.) 617-969-7100. EDC is a nonprofit organization that does research and development work in education, including curriculum development. ●

ASCD **A Diverse, International Community of Educators, Forging Covenants in Teaching and Learning for the Success of All Learners**

CURRICULUM UPDATE

Scott Willis, Editor
Philip Cohen, Staff Writer

Gene Carter, *Executive Director*
Ron Brandt, *Executive Editor*
Nancy Modrak, *Manager, Editorial Services*
Carolyn Pool, *Associate Editor*
Stephanie Justen, *Asst. Manager, Production Services*
Gary Bloom, *Manager, Design and Production Services*
Karen Monaco, *Senior Graphic Designer*

1995-1996 Executive Council:
Charles Patterson (Pres.), Frances Fairchild Jones (Pres.-Elect), Art Steller (Immediate Past Pres.), Jan Adkisson, M. Kay Awalt, Brenda Benson-Burrell, Margy Chow, Douglas Gruber, Edward Hall, Joanna Choi Kalhus, Margret Montgomery, David Rainey, Charles Schwahn, Judy Stevens, Sherrelle J. Walker, Isa Kabal Zimmerman

Curriculum Update is published four times per year as a supplement to *Education Update*, the official newsletter of the Association for Supervision and Curriculum Development, 1250 N. Pitt St., Alexandria, VA 22314-1453. Telephone: 703/549-9110 (switchboard hours are 8 to 5, Monday through Friday, Eastern Time).
Copyright 1995. Internet e-mail: update@ascd.org. Copyright 1995.

Duplication Policy: If you are an ASCD member, you may make up to 100 copies of two pages or less of *Curriculum Update*, provided that each copy includes a full citation of the source. If you wish to copy more than that, or if you are not an ASCD member, please submit your copying request to the Copyright Clearance Center, 222 Rosewood Dr., Danvers, MA 01923. Phone: (508) 750-8400. Fax: (508) 750-4470. Requests to reprint material from *Curriculum Update* should be directed to Mary Riendeau at ASCD.

Subscriptions to this publication are included in ASCD membership; but additional copies may be ordered (prepaid only) at the following rates:

1 copy	$1.00 and SASE
10 copies	$12.50
25 copies	$20.00
50 copies	$30.00
100 copies	$50.00

When ordering, please cite stock no. 1-95186.

Student-Centered Inquiry

Ramon E. Lopez and Jan Tuomi

A national consensus is evolving around what constitutes effective science education. It is reflected in an array of publications, including *Science for All Americans* (1989), *Benchmarks for Scientific Literacy* (1993), and *National Science Education Standards* (1994). These documents share two common convictions: (1) all students, and especially underrepresented groups (Oakes 1990), need to learn scientific skills, such as observation and analysis; and (2) these skills should be imparted in a "less is more" curriculum that begins in elementary school before kids form negative attitudes toward science.

As any scientist knows, the best way to learn science is to do science. This is the only way to get beyond dry facts to the real business of science—asking questions, conducting experiments, collecting data, and looking for answers. In elementary school, the best way to accomplish this is to examine natural phenomena that are brought into the classroom and studied over time. Active, hands-on, student-centered inquiry, in which kids learn to apply scientific problem solving, should be at the core of science education.

Elements of Success

With new materials available, a better understanding of how to do things, and a national consensus that reform is critical to our future, many school districts have begun to reform their elementary science programs systemically, that is, to revamp all elements of the system and institutionalize the changes. What does this entail? Four basic components:

1. Good teaching materials. These should be research-based, developmentally appropriate, designed by educators and knowledgeable scientists, and thoroughly field-tested. They should enable children to conduct long-term investigations (say, eight weeks), not with a series of single-shot activities, but with activities that build upon one another. The activities should encourage inquiry, address a variety of learning styles, and connect to other parts of the curriculum.

Excellent examples of such materials are found in *Science and Technology for Children* (Carolina Biological), *Insights* (Optical Data), and the *Full Option Science System* (Britannica). As for costs, it is often no more expensive to maintain a hands-on science program than a textbook program. Schools should use their resources to buy the best curriculum for their needs, knowing that teachers may develop additions or modifications after some experience with the units.

2. A materials support system. Because teachers do not have time to gather the needed materials, a science kit should arrive at a specified time with the materials the entire class needs for several weeks. When the unit ends, the kit can be picked up, refurbished at a central location, and sent to the next scheduled teacher.

3. A vigorous and ongoing professional development program. Teachers need to work through the units themselves and learn how to teach them. They need to be able to ask questions—particularly about classroom management—of more experienced teachers. They may also need support to overcome their fear of science and to realize that they, too, can become scientists. Administrators also need to experience what hands-on science is all about in order to support and evaluate an innovative program. Both need to understand that the statement "I don't know, but maybe we can find out" is the starting point for all inquiry.

4. New assessment tools. A bad standardized test can cause teachers and administrators to resist a good hands-on program. Performance-based testing and portfolios are preferable. Teachers may need inservices in the new assessment techniques, and parents and school boards will have to be kept abreast of the changes in grading.

To implement and sustain such a program, one needs to build community and administrative support and maintain it.

No New Discovery

The idea of hands-on science is not new. In the 1960s and early '70s, the National Science Foundation supported the development of hands-on teaching materials, such as the kits developed in the Elementary Science Study program and the Science Curriculum Improvement Study. Research showed that these materials were better at teaching science concepts and skills than were traditional textbooks. Well-designed materials also allowed all children to experience success in science, including kids who are good artists or communicators or who have superior hand-eye coordination.

Why, then, didn't these programs become the core of instruction? Partly because in most places, these kits were simply turned over to teachers who had little or no idea of how to use them effectively. Because elementary teachers generally have an inadequate science background, they naturally felt uncomfortable with the materials. Student inquiry meant a lot of noise and mess; materials didn't work right or were used up. What's more,

Lopez, R., and J. Tuomi. (May 1995). "Student-Centered Inquiry." *Educational Leadership* 52, 8: 78–79.

© Jeff Tinsley/Smithsonian Institution

teachers feared that if they didn't cover all the material in the textbooks, their school's scores on the standardized tests would go down. And how do you grade kids for hands-on science anyway?

To this day, in school science closets and basements around the country, old science kits can be found with half the stuff broken or missing, or still in the shrink wrap because teachers were too intimidated to open them.

Finally: Breakthroughs

Not everyone shrank from the problems. Many educators found ways to refurbish the kits and buy replacement parts in bulk, to train teachers, and to grade hands-on science. In 1985, Doug Lapp, an elementary science program designer, founded the National Science Resources Center as a joint organization of the National Academy of Sciences and the Smithsonian Institution. The center, based in Washington, D.C., collected information about schools that had managed to sustain hands-on science programs for years or, sometimes, decades. The center then conveyed that information to other school districts.

About the same time the National Science Foundation began to fund curriculum development for a new generation of kit-based materials. These materials have gone through a rigorous research and development cycle, incorporating the best of earlier programs. They also have benefited from subsequent research in developmental psychology.

Such reforms in science education have been far-reaching. In the many communities that have succeeded in their reform efforts, scientists and engineers, as well as scientific and technical corporations, universities, national laboratories, and science museums have played critical roles. They have generated public awareness and support, and assisted with professional development and fund-raising.

The bottom line is this: We know what works for kids, we have a pretty good idea how to make it work in schools, and the help is out there to make it happen. ■

References

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.

National Committee on Science Education Standards and Assessment. (November, 1994). *National Science Education Standards "Headline" Summary* (draft). Washington, D.C.: National Research Council.

Oakes, J. (1990). *Lost Talent: The Underparticipation of Women, Minorities, and Disabled Persons in Science*. Santa Monica, Calif.: Rand Corporation.

Rutherford, F. J., and A. Ahlgren. (1989). *Science for All Americans*. New York: Oxford University Press.

Ramon E. Lopez is Director, Education and Outreach Programs, The American Physical Society, One Physics Ellipse, College Park, MD 20742. **Jan Tuomi** is Director, Regional Initiatives in Science Education, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418.

PCS May Be Teaching Kids the Wrong Lessons

BY LAURIE HAYS

Staff Reporter of the Wall Street Journal

Sarah Kahn sees it as the battle of the screens.

In the family room of her New Canaan, Conn., home, three of her children flit from the TV set to the Game Boy to the PC and back again. "I say, 'Turn that TV off.' They go right to the next screen," says Dr. Kahn, a gastroenterologist. "The PC has the same pull as the TV."

Many parents think it's great when their kids flip on the computer, figuring that computers are educational and, at the least, less passive than television. "But here's the bad news: Most educational software isn't, alas, all that educational, and it can have many of the same ill effects as the boob tube."

Certainly PCS have great potential for promoting learning and creativity. Kids with short attention spans or those in need of remedial help can benefit from the lively graphics, sound and novelty of drill programs. Even if a program isn't perfect, when children and parents play it together, the kids get some benefit. And, after all, learning how to use a computer is good preparation for the future.

But PCS can also promote passivity, dull creativity and limit socialization in children, taking away from more important kinds of play, educational experts say. In some circles, fears are growing that a new generation bred in the "pop" PC world will suffer the same effects as the so called TV generation, with some kids emerging unable to reason well or communicate effectively.

"PCS, for the most part, are a debased form of play. It isn't the kind of imaginative play that young kids will indulge in if allowed to use their own resources," says Marie Winn, who in 1977 wrote "The Plug-In Drug," a book on the impact of television on children.

Some education experts believe fully 75% of the hundreds of software titles aimed at children don't teach much at all. Kids aren't "learning" as much as drilling by pointing and clicking. The ideas come from the software rather than the children, who respond by rote rather than by using their own thought processes.

Part of the problem is that even noncomputerized drill work is sharply at odds with "whole language," a popular educational approach that teachers children academic skills through an integrated curriculum.

But even some kids are critical. Eleven-year-old Jessica Djilani fooled around with drill programs at home in Scarsdale, N.Y., but found herself "just sitting there like a vegetable. It's like watching TV. You feel disgusting," she says.

Pat Aufderheide, associate professor of communications at American University, limits TV time for her six-year-old son and four-year-old daughter and is astonished by how "engaged and interested they are in computer games. After her son told her, "This is almost like TV," she realized how addicted he had become and began limiting his PC time, too.

Software makers call their wares "drill for skill," but some doubters prefer "drill and kill" because so many of the titles adopt shoot-em-up game techniques. This simplistic approach requires little direct help from mom and dad.

But that's the point, critics say. "Publishers want something that's easy to run, will catch the child's fancy and doesn't require parental assistance—because that's what will sell," says June Wright, a professor of early childhood education at Eastern Connecticut State University. Adds Joseph Parness, a developer of multimedia titles for Jostens Learning Co., "The majority of educational titles continue to prove to be nothing more than whimsical 'edutainment' products that have evolved into the fast foods of learning."

Reader Rabbit, an enormously popular series, is a frequent target of critics. Published by Learning Co., it has sold more than two million copies since it was first released in 1984, and last year it led the half-billion-dollar-a-year education market. In one of the programs, Reader Rabbit's interactive Reading Journey, a cartoon hare guides preschoolers and older kids through a series of games, sounding out words and hopping through books as children point and click.

All this looks educational, and many children love it. So do parents. Cheryl Truett of Canton, Ohio, says her six-year-old daughter, Shannon, a kindergartner, spends hours on Reader Rabbit and has taught herself to read. Mrs. Truett also finds the PC's electronic baby-sitting role convenient. It gives her time to do housework when Shannon is home in the mornings.

But a recent study of 49 children in Missouri found that those who used Reader Rabbit and similar drill programs for six months at their preschool had a 50% drop in creativity, as

measured by a standardized test, with no statistically significant gains in learning how to read.

The problem is that when words are taught as isolated objects they don't have real meaning, says Susan Haugland, the child-development professor at Southeast Missouri State University who ran the study.

In addition, her study found, children frequently play these games by randomly clicking on words until they find the right ones or memorizing the story, making it seem as though they are reading. Kids also tend to gravitate toward the least educationally useful aspects of a program when left to navigate it on their own.

The study also cited a discouraging addiction factor: Children using these programs, bent on competing to "win," were glued to the screen three times as long as those who used "developmental" software that was less game-like.

While some parents say they don't see the harm, Dr. Haugland opposes using such sophisticated, expensive gear to do the same flash-card job that a piece of paper and pencil can do.

Pat Walkington, vice president at Learning Co., defends Reader Rabbit: "I wouldn't say that it's better than a teacher or a parent, but it's very effective and engaging." A company spokeswoman adds that it beats violent computer games. "It does enhance learning—would you rather have them playing Doom?"

Math is another problem area. At Dr. Kahn's home, the two boys, Sam and Jake, are engaged in a prebedtime game of Math Blaster. The putative point of the game is to practice adding, subtracting and multiplying. But Jake, six years old, says he sees the object as "we get to shoot down spaceships." Nine-year-old Sam likes playing the program, too, but his mother says it's way too simple for him—"a waste of time."

Many educators say they believe children need to learn how to think through math problems rather than simply memorizing a list of answers. Yet "a steady diet of these programs makes you want to memorize and get the right answers," says Douglas Clements, a professor of math education at the State University of New York's Buffalo campus. What's more, after all the multimedia gizmos and games, kids may balk at doing math the boring, old-fashioned way, with pencil and paper.

Social interaction is also lost in most PC play. When children play together or with adults, discussions and disagreements ensue, teaching them to get along and see other points of view, experts say. Alone at the PC that doesn't happen.

Some experts say children can also lose a sense of empowerment with most PC software. Popular titles offer a predetermined set of options, automatically limiting a child's imagination. In small doses, this is probably fine, the experts say, but most children would still be better off sitting down with crayons and paper and making their own pictures or stories—or even, occasionally, doing nothing at all.

When kids play an old board game, they make up their own rules as they go along, notes Ms. Winn, the "Plug-In Drug" author. "Creating their own images helps children work out problems and resolve powerlessness," she says. "On the computer, the machine has all the power to make the rules."

Some Software Nurtures Creativity

BY LAURIE HAYS

Staff Reporter of the Wall Street Journal

For those who believe computers have potential for teaching, there is hope.

At the Edgewood School in Scarsdale, N.Y., 14 fifth-graders sit in pairs in a spacious, brightly lit computer classroom, working on Macintoshes. Using concepts from math class—angles, multiplication, greater-than and less-than variables—they have designed on-screen pinball games and are now testing them.

The projects are a team effort. Jessica, age 11, and Tom, 10, argued at length before finally agreeing to create a soccer game. Each movement required a command, which the children programmed themselves. Their ball now ricochets at a 170-degree angle because, after much trial and error, that angle "looked the most realistic," Jessica says.

The children are pleased with their results, which took them about six hours. "It's my favorite part of the day," Jessica says of computer class. "Both of us hate math, but math on the computer is fun. We look at what we've done and say, 'Aren't we smart.'"

Gerald Crisci, the school district's elementary school computer coordinator, says children should use computers to apply what they have learned to "do" and "make" things. That's why he recommends that kids wait to use computers until they reach the third grade and can apply basic skills. "Computers shouldn't be used for feeding kids information," he adds.

Mr. Crisci has third-graders create snowflakes in 3–D. The fourth-graders are putting together and programming animated zoos, drawing on their study of endangered species in science. Students have to remember fine points, he says, such as the need to avoid putting predators and prey in the same habitat.

After the fifth-graders finish their pinball games, they plan to make bar charts of the books the class has read this year, separating them by title, genre, length and popularity. Earlier this year, they did an immigration project using a database that included real manifests from ships that landed in Boston Harbor in 1840. Every team was given a family, and the goal was to set the family up in the New World with a balanced budget. This required using the database to find jobs, housing and even mates.

In all of the Edgewood School's software, there is very little pointing and clicking and no animated figures that haven't been created by the children themselves. Teachers shun drill software because they believe they can do a better job on basic skills themselves. "We know what we want to teach. The computer doesn't," explains fourth-grade teacher Barbara Black.

Mr. Crisci created most of the curriculum from scratch, using a language called MicroWorld's Logo from Logo Computer Systems Inc. and a software package called ClarisWorks from Apple Computer Inc.'s Claris subsidiary. There isn't much commercially available software that he considers truly educational.

Some industry executives say that is changing. As computers become more powerful and designers get more sophisticated, a new genre is emerging, they say. Multimedia programs that let children write and draw and create simulated villages, cities and their own characters are starting to appear.

Roger Schank, director of the Institute for the Learning Sciences at Northwestern University in Evanston, Ill., loathes the use of animated bears to teach children to read and laments the popularity of putting books on CD-ROM.

The software industry needs to invent a new way of learning, he maintains. He is working on "Broadcast News," a software program that lets kids make a TV news show, incorporating history, math and current events. "We are prepared to do better things," he says, if commercial companies will go along.

Jon Goldman, chief executive of ImaginEngine, a small software company in Mountain View, Calif., started out with a service that encourages children to write letters to characters by mailing back computer-generated responses that appear handwritten. Now he pursues software that will let children design their own computer characters and give them personalities.

"Just because we haven't reached the promised land of software excellence," he says, "doesn't mean that it's a mirage."

Choosing a Program

Some programs that educators recommend:

Primary Grades: My Own Stories, Storybook Weaver, both by MECC; Imagination Express, Edmark; Kid Pix, Broderbund. The Print Shop, Broderbund; Kid Works 2, Davidson.

Middle School: The Students Writing Center, Learning Co; SimTown, Maxis; HyperStudio, Roger Wagner Publishing; Amazing Animation, Claris; Fine Artist, Microsoft; Kid Cad, Davidson; Project Builder, MicroWorld.

High School: SimCity and SimCity 2000, Maxis; HyperCard, Apple; SuperCard, Allegiant.

Note: Most of these programs require adult support.

Other Video Programs Available from ASCD

Action Research *(4-tape series)*

Adult Conflict Resolution

Another Set of Eyes *(5-tape series)*
- Techniques for Classroom Observation
- Conferencing Skills

Becoming a Star Urban Teacher *(7-tape series)*

Challenging the Gifted in the Regular Classroom

Constructivism *(2-tape series)*

Cooperative Learning *(5-tape series)*

Dimensions of Learning Training Program and Video Package

Early Childhood Education: Classroom Management—Curriculum Organization

Effective Schools for Children at Risk

Inclusion *(3-tape series)*

Integrating the Curriculum *(2-tape series)*

Involving Parents in Education

Learning About Learning

Making Meaning: Integrated Language Arts Series *(5 tapes)*

Mentoring the New Teacher *(9-tape series)*

Motivation to Learn *(2-tape series)*

Multicultural Education

Multiple Intelligences *(3-tape series)*

Opening Doors: An Introduction to Peer Coaching *(2-tape series)*

Outcome-Based Education *(4-tape series)*

Redesigning Assessment *(3-tape series)*

Reporting Student Progress

Restructuring America's Schools

Restructuring the High School: A Case Study

Schools of Quality

Shared Decision Making *(2-tape series)*

Teaching and Learning with Technology

Teaching Strategies Library *(9-tape series)*

Teaching to Learning Styles

Video Library of Teaching Episodes *(30 tapes)*

What's New in School *(4-tape series)*

For information on how to purchase or preview these programs, call ASCD's Customer Service Center at (703) 549-9110 or 1-800-933-2723.

1995–96 ASCD Executive Council Members and Executive Director

Janice Adkisson, M. Kay Awalt, Brenda Benson-Burrell, Gene R. Carter, Marge Chow, Edward Hall, Frances Faircloth Jones, Joanna Choi Kalbus, Margret Montgomery, Charles Patterson, David Rainey, Charles Schwahn, Arthur Steller, Judy Stevens, Sherrelle J. Walker, Isa Kaftal Zimmerman

DEVELOPED BY
TEACHERS' VIDEO WORKSHOP

DISTRIBUTED BY
ASSOCIATION FOR SUPERVISION
AND CURRICULUM DEVELOPMENT

BEST COPY AVAILABLE